AN ANALYSIS OF ESTIMATE AT COMPLETION
MODELS UTILIZING THE DEFENSE ACQUISITION
EXECUTIVE SUMMARY DATABASE

THESIS

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The views expressed in this thesis are those of the authors and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

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Preface

This study investigates the assertion that the Cost at Completion is bounded below by the Cost Performance Index-based Estimate at Completion (EAC) and above by the Schedule Cost Index-based EAC. The hypothesis is tested on a selective sample of 321 contracts from the Defense Acquisition Executive Summary Database. This thesis checks the validity of this assertion and explains the usefulness of this information.

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Mark Terry and Mary Vanderburgh

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Abstract

This study explores the widely held assertion that DOD contract Cost at Completion is bounded below by the Cost Performance Index-based Estimate at Completion (EAC) and above by the Schedule Cost Index-based EAC.

Descriptive statistics determined the floor and ceiling for 321 DOD contracts. The results confirmed that the Cost Performance Index-based EAC is a reasonable floor and the Schedule Cost Index-based EAC is a reasonable ceiling for EAC formulas. For the contracts considered overall, on average, the Cost at Completion was not bounded by the floor and ceiling. The range of EAC formulas evaluated tended to slightly underestimate the Cost at Completion on average.

Results were tested for sensitivity to Index Type (cumulative, six-month and three-month), Program Phase, Contract Type, Branch of Service, System Type, Major Contract Baseline Changes and Management Reserve.

Graphs of the EAC ceilings and floors for several contract categories illustrate trends in program status throughout various stages of contract completion. These graphs should assist program analysts in providing program managers with reasonable contract completion cost estimates for contracts in various categories across all stages of contract completion.

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I. Introduction

General Issue

The Reagan Administration was elected in 1980 with a primary goal of rebuilding the nation's defense capability. A significant portion of this rebuilding effort included the development and production of needed major weapons systems for each of the service components of the Department of Defense (DOD).

Though similar problems in the weapons procurement system had been identified in post-World War II systems development, the build-up during the Reagan years brought increased scrutiny and great criticism on systems acquisition and, specifically, on cost and schedule overruns.

This heightened emphasis on cost and schedule overruns brought concern from both the executive and legislative branches of government. In March 1981, in a memorandum to Defense Secretary Weinberger, President Reagan voiced executive direction:

> We were concerned, as I am sure you were, to learn of the significant cost growth in a number of Defense programs . . . (10:33)

Similar thoughts were expressed by the Chairman of the Defense Appropriations Subcommittee, Rep Joseph P. Addabbo (D-NY) in the same year:

> We must give a strong message to the Defense Department that the old way of doing business will not be tolerated. . . . Unless we demonstrate we are getting a handle on cost overruns, we'll lose what appears to be a consensus to rebuild our military forces. (10:34)

As the Reagan Administration progressed, political pressure mounted regarding the management of major weapons systems programs. In 1985, Senators Goldwater and Nunn, generally viewed as hawks on defense issues, produced a report echoing the continuing concern of Congress over cost and schedule increases. This, in part, led to a major study headed by former Deputy Defense Secretary David Packard, known as the President's Blue Ribbon Commission on Defense Management. This report stated that:

> . . . too many of our weapons systems cost too much, take too-long to develop, and by the time they are fielded, incorporate obsolete technology. (16:337)

This developing consensus, combined with federal deficit pressures and declining threat assessments, seriously damaged the political will present in 1980 to develop, produce and field defense weapons systems.

The A-12 program cancellation in 1991 graphically illustrated that cost and schedule overruns would no longer be met with additional funding and the acceptance of slipped development and production time frames.

Background

Though cost overruns of major weapons systems gained heightened attention during the build-up of the U.S. defense budget during the Reagan Administration, historical evidence indicates the presence of comparatively higher overruns of systems produced and developed 30 years prior (13:51). A study by Merton Peck and Frederick Scherer of 12 major weapons systems produced in the 1950's detailed average cost growth, from start to full-scale development, of 220 per cent (15:412). A similar RAND Corporation study, published in 1986, notes a range, in relation to current programs, of approximately 10 to 35 per cent (18:9).

One of the major factors in the decline of the amount of cost overruns was the introduction, during the tenure of Secretary McNamara at the Department of Defense, of a set of criteria known as Cost/Schedule Control Systems Criteria (C/SCSC). The development of this evaluation method occurred after it was apparent to DOD officials that the prior methods to monitor contract performance

were inadequate to properly gauge major weapons systems programs.

Prior to C/SCSC, it was not uncommon for contractors to bid low on prospective contracts, which were based primarily on fixed fee assumptions, and then petition for alterations to the contract length and price during the performance phase stating that they had not realized how complex and costly the system production would actually be. The government was often unaware of these problems until significantly into the time span of the contract and therefore its leverage to mandate changes to solve these problems was limited. This template for disastrous cost and schedule overruns necessitated the development of an evaluation method to better monitor cost and schedule performance (8:22).

A key component of the C/SCSC system is the Estimate at Completion (EAC) calculation, the estimation of the total program cost that may be computed throughout the program life-cycle based upon schedule and cost data. This figure is used to estimate the cost variance of a program from its original baseline and is an essential driver in the analysis of program efficiency and effectiveness.

Even with the relative improvement in accounting measures to analyze contractor performance, the lack of standardization in the use and interpretation of EAC

formulas remains a problem. Most recently, in the Memorandum for the Secretary of the Navy, Subj: A-12 Administrative Inquiry (the Beach Report) on the factors surrounding the cancellation of the U.S. Navy's A-12 program, cost estimation procedures were still found woefully lacking due in part to disagreements about selection of and possible manipulation of EAC formulas (1:12-13).

As a remedy to potential EAC manipulation, the Beach Report recommended a range of EACs be used in future program evaluations (1:16). A range of EACs will, due to the relative accuracy of the various models based upon contract characteristics and stage of completion, provide a wider "confidence interval" to estimate program cost (9:3).

Further, the Beach Report advised changes to the DOD 5000 series documents indicating the Cost Performance Index (CPI) should be used as a benchmark formula for programs over 15 per cent complete.

> (1) Enter the range of estimates at completion, reflecting best and worst cases.
>
> (2) Provide the estimate at completion reflecting the best professional judgment of the servicing cost analysis organization. If the contract is at least 15 per cent complete and the estimate is lower than that calculated using the cumulative cost performance index, provide an explanation.
>
> (3) Justify the program manager's best estimate (item 25) if the contract is at least 15 per cent complete and the estimate is lower

than that calculated using the cumulative cost performance index. (7:16-H-6)

The CPI was chosen as a baseline EAC due to evidence suggesting its relative stability as a predictor of program cost from the 20 per cent completion point across a variety of program and contract types (4:7).

The Schedule Cost Index (SCI) is generally viewed to be the high-end EAC formula (9:9). This method is theoretically most pessimistic because it utilizes "equally" both schedule and cost data in its calculations with potential performance negatives in each measure amplifying the other, generating a higher total EAC.

Though extensive research in the C/SCSC and EAC area has been conducted for approximately 20 years, significant room for cost estimation process refinement and specification remains. Specifically, while the CPI and SCI have been established in practice as the de facto floor and ceiling, respectively, for EAC models, research on a large, diverse program database has not definitely supported these contentions.

Research supporting the EAC ceiling and floor assertion would be most useful to program managers and the DOD cost community as it would allow them to establish an area in which the Cost at Completion (CAC) would most probably be contained. Also, it would confirm existing suspicion that program cost estimates outside this range

are unrealistic and require a heightened degree of explanation and justification.

Finally, the trend toward declining defense budgets and increasing scrutiny of defense acquisition policy magnifies the importance of improving the management and control of weapons system costs.

Research Problem

The primary objective of this research is to test the DOD assertion in DOD 5002.2-M, Defense Acquisition Management Documentation and Reports and Office of the Under Secretary of Defense for Acquisition (OUSD(A)) concept that the Cost Performance Index (CPI)-based EAC is a valid floor and the Schedule Cost Index (SCI)-based EAC is a valid ceiling for EAC formulas (7:16-H-6). Additionally, this research explores the position of the Cost at Completion relative to the EAC floor and ceiling.

Specific Problem Statement

Does available program data on completed DOD contracts establish a range of EACs consistent with DOD policy and assumptions? The primary hypothesis to be tested:

H_O: Cost at completion is bounded below by the CPI-based EAC and above by the SCI-based EAC.

The hypothesis was answered using a database described below. In addition to the CPI and SCI-based EACs, the SPI-based EAC was selected, for a total of three EAC formulas.

The hypothesis test starts with determining the percentage deviations of each of four EAC formulas from the actual CAC. These percent deviations from CAC provided a normalized set of data points for comparative purposes. The percent deviations from CAC were averaged and the EAC with the highest average percent deviation from the CAC became the ceiling and the EAC with the lowest average became the floor.

The hypothesis was valid only if the SCI-based EAC was the ceiling, the CPI-based EAC was the floor, and if the floor and ceiling bounded the Cost at Completion.

The results of the hypothesis test were tested for sensitivity to several factors, including Index Type, Contract Completion Stage, Program Phase, Contract Type, Branch of Service, System Type, Major Baseline Changes and Management Reserve.

The specific categories for sensitivity analysis are addressed with investigative questions, following a brief description of the database used in this analysis.

Defense Acquisition Executive Summary Database

OUSD(A) provided program data, compiled from contractor cost management reports since 1972, in a database known as the Defense Acquisition Executive Summary (DAES). This database contains performance data on over 500 major weapons system programs (major defined as research, development, test and evaluation contracts over $60 million and production contracts over $250 million) from each of the service branches (19:5).

Investigative Questions

1. Which EAC models are most utilized in the Department of Defense (DOD) and why?
2. Of the index-based EACs compared, is the CPI-based EAC the floor and is the SCI-based EAC the ceiling?
3. Does the final Cost at Completion lie within the considered range of EACs?
4. Which EAC is the most accurate predictor of final Cost at Completion?
5. Are the original hypothesis test results (answers to questions two through four) sensitive to:
    a. Index Type (Cumulative, Six Month or Three Month)
    b. Program Phase (Pre-Production or Production)
    c. Contract Type (Cost Plus, Firm Fixed or Fixed Price)
    d. Service (Army, Navy or USAF)

e. System Type (Airframe, Electronics, Engine, Equipment, Ground, Missile, Ship or Space)

f. Major Baseline Changes (Not OTB or OTB)

g. Management Reserve

6. Are the original results and the results for each category sensitive to the Contract Completion Stage?

The first question will be answered in the literature review. The remaining questions will be answered after analysis of the DAES database.

Scope/Limitations

The primary scope of this thesis is utilization of the DAES database to analyze the concept that CAC is bounded below by the CPI-based EAC and above by the SCI-based EAC. Additional analysis focuses on the sensitivity of the ceiling and floor to various conditions as described in the investigative questions.

The chief limitation of this thesis is the quality and consistency of the DAES database. The database exhibited inconsistencies in terms of the time between consecutive entries of program cost and schedule data. A process of interpolation within the initial contract data provided the information necessary to minimize this shortcoming.

Having provided a general overview, a discussion of the specific problem statement and an outline of the

investigative questions, it is useful to expand on the background and significance of this research with a review of applicable literature.

II. Literature Review

This section addresses the development of C/SCSC, defines the data elements used in EAC calculations and reviews appropriate and applicable EAC comparison studies.

The McNamara Era in the DOD saw the introduction of many concepts used in the civilian sector to the management of national defense. Two mechanisms introduced prior to the development of C/SCSC were attempts to solve the same problems, but met with limited success. Program Evaluation and Review Technique (PERT) and the Critical Path Method (CPM) were industry and academic concepts that were essentially techniques to monitor and optimize the scheduling side of the equation. Though these techniques were a step in the right direction regarding schedule monitoring, they did not initially take into account the cost element, and additionally were fought by members of both the military and contractor communities due to the implementation style of McNamara's "whiz kids" (8:23). A by-product of the introduction of these concepts was the initiation of DOD to the "earned value" theory, the conceptual linchpin of C/SCSC. This method of analyzing contract performance:

> . . . suggested the idea of planning a program and the necessary resources in sufficient detail so as to allow for the precise measurement of performance along the way, and of having the ability to obtain reliable estimates of the total

costs, and total times needed to complete the various programs. (8:23)

The genesis of C/SCSC was the formation of a United States Air Force body known as the Cost/Schedule Planning and Control Specification Group. This group was tasked to develop criteria that would not replace the internal management control systems of defense contractors but would rather provide the government with a means to evaluate a contractor's present systems in relation to cost control and schedule performance (8:24).

In late 1967, the Air Force study group's efforts resulted in the publication of DOD Instruction 7000.2, Performance Measurement for Selected Acquisitions. This document introduced 35 criteria that are partitioned into 5 major areas:

> *Organization*--To define the contractual effort with use of a work breakdown structure, assign responsibilities for performance of the work, and accomplish all this with use of an integrated contractor management control system.
>
> *Planning and Budgeting*--To establish and maintain a performance measurement baseline for control of the work.
>
> *Accounting*--To accumulate the costs of work and materials in a manner which allows for comparison with earned value.
>
> *Analysis*--To measure earned value, to analyze variances of both costs and schedules, and develop reliable estimates of costs at completion.
>
> *Revisions and Access to Data*--To incorporate changes to the controlled baseline as required, and allow appropriate Government representatives

> to have access to contract data for determining contract compliance. (8:26-27)

The analysis criteria ensure that data collected and maintained by the contractor include sufficient information to allow the government to analyze contractor performance. Program managers:

> . . . require a comparison of actual vs. planned performance, calculation of variances, and analysis of variances (if they exceed predetermined thresholds). (11:13-18)

The measures or ratios that the government uses to deduce the quality of contractor performance include Budgeted Cost of Work Scheduled (BCWS), Budgeted Cost of Work Performed (BCWP), Actual Cost of Work Performed (ACWP), Budget at Completion (BAC) and Estimate at Completion (EAC) as defined in Appendix A. Additional useful measures include Management Reserve (MR), Total Allocated Budget (TAB), Percent Complete (PC) and Cost at Completion (CAC), also defined in Appendix A.

The basic EAC formula used in this analysis is index-based.

$$EAC = ACWP + (TAB - BCWP)/index \qquad (1)$$

Index Definitions

1. Cost Performance Index (CPI). The CPI is obtained by dividing BCWP by ACWP. A ratio greater than one (BCWP>ACWP) indicates a cost underrun. A ratio less than one (BCWP<ACWP) indicates a cost overrun. The three CPIs analyzed include cumulative, six-month and three-month, as defined below.

$$CPIcum = BCWPcum/ACWPcum \quad (2)$$

$$CPI6 = \sum_{i=0}^{-5} BCWP / \sum_{i=0}^{-5} ACWP \quad (3)$$

where i represents the month and goes from current (i=0) to five months prior (i=5) to provide the six most recent data points.

$$CPI3 = \sum_{i=0}^{-2} BCWP / \sum_{i=0}^{-2} ACWP \quad (4)$$

2. Schedule Performance Index (SPI). The SPI is the ratio of BCWP to BCWS. A ratio greater than one (BCWP>BCWS) indicates a program is ahead of schedule while a ratio less than one (BCWP<BCWS) indicates a program is behind schedule. The cumulative, six and three month SPIs are defined below.

$$SPIcum = BCWPcum/BCWScum \quad (5)$$

$$SPI6 = \sum_{i=0}^{-5} BCWP / \sum_{i=0}^{-5} BCWS \qquad (6)$$

$$SPI3 = \sum_{i=0}^{-2} BCWP / \sum_{i=0}^{-2} BCWS \qquad (7)$$

3. Schedule Cost Index (SCI). The SCI is the product of CPI and SPI. Cumulative, six and three month indexes are defined below.

$$SCIcum = CPIcum * SPIcum \qquad (8)$$

$$SCI6 = CPI6 * SPI6 \qquad (9)$$

$$SCI3 = CPI3 * CPI6 \qquad (10)$$

Having acknowledged the index definitions, additional clarification of the relationship between an index and its corresponding EAC is best illustrated with an example. The following example meets the conditions of the hypothesis. The relative ranking of EACs results in the CAC bounded by the SCI-based EAC as the ceiling and the CPI-based EAC as the floor.

Example of Index/EAC Relationship

A typical contract might be expected to be behind schedule and over cost. This condition is exemplified with CPI and SPI values both less than one.

Let TAB=100   BCWP=27   BCWS=33.75   ACWP=30   CAC=125

INDEX CALCULATIONS: CPI=BCWP/ACWP=.9

SPI=BCWP/BCWS=.8

SCI=CPI*SPI=.72

EAC CALCULATIONS: EAC = ((TAB-BCWP)/index)+ACWP

EAC_{CPI}=((100-27)/.9)+30=111.11

EAC_{SPI}=((100-27)/.8)+30=121.25

EAC_{SCI}=((100-27)/.72)+30=131.9

When CPI and SPI are less than one, their product (SCI) will be less than either CPI or SPI. This example illustrates how the lowest index (SCI) has the highest corresponding EAC, since the index falls in the denominator of the basic EAC formula.

Understanding the mechanics of the indexes, the EACs, and how they relate to each other paves the way for further exploration into the significance of EACs through a review of EAC literature to date. A review of several comprehensive EAC studies follows to help the reader appreciate the variety of conclusions to date. These studies are summarized in Table 1.

TABLE 1

SUMMARY OF EAC RESEARCH

Author Year)	Source	Topic	Type/Number of Contracts	Conclusions
Bright & Howard (1981)	Army	EAC Formulas	11 development	EAC selection should be based upon program characteristics; SCI6 suggested optimal
Covach, Haydon & Reither (1982)	Air Force	EAC Formulas	15 development 6 production	CPI variations most accurate
Reidel & Chance (1989)	Air Force	EAC Formulas	16 development 40 production	No single EAC method produces optimal estimates for all types of programs
Beach (1990)	Navy	Cancellation	1 development	EAC calculations vary greatly & are easily manipulated
McKinney (1990)	Air Force	EAC Formulas	N/A	Provided history and review of EAC research
Christensen, Antolini & McKinney (1992)	Air Force	EAC Formulas	N/A	Accuracy of regression-based formulas over index-based not supported
Fleming (1992)	Civilian Contractor	EAC Formulas	N/A	CPIcum is middle range formula; SCIcum is high end formula
Christensen (1993)	Air Force	EAC Formulas	N/A	EAC formula accuracy depends upon system type, phase and type of contract
Christensen & Heise (1993)	Air Force	CPI Stability	62 development 93 production	CPIcum is stable from the 20% completion point

EAC Comparison Studies

The EAC foracasts the completed cost of a defense contract and provides a basis to systematically project total weapons system cost, a necessary and key component of the governmental oversight process lacking in the era prior to C/SCSC. Calculation and analysis of EAC data provides the ability to determine the relationship of cost and schedule parameters throughout the program life-cycle, allowing the government a mechanism to identify and minimize cost and schedule overruns.

Numerous attempts have been made to compare and contrast the performance of various EAC formulas based upon what invariably have been rather small and homogeneous weapons systems databases.

In 1980 and 1981, the ManTech International Corporation, in a study contracted by the U.S. Navy, tested 24 EAC formulas on a database of 15 development and 6 production contracts. Twelve of these formulas were index-based with the remainder regression-based (5:1-7, 62-65). Also in 1981, Bright and Howard tested 11 EAC formulas on 11 U.S. Army development contracts. Nine of the formulas were index-based with the remainder regression-based. These studies concluded that regression-based formulas tend to perform well in the early stages of completion. The index formulas that performed the best across all three stages were CPI-based

They also recommended the SCI-based EAC as a candidate for the most accurate predictor of Cost at Completion (3:217-221).

In 1989, Reidel and Chance tested 6 index-based formulas on a U.S. Air Force database consisting of 16 development and 40 production contracts. These programs were evaluated at four finite stages of completion versus the early, middle and late range methods of the ManTech and Bright and Howard studies. Their results indicated that SCI and CPI-based models performed well across all stages of completion (17:3-6, 72-78).

Regarding empirical support of the CPI-floor and SCI-ceiling assertions, the available studies are suggestive but not conclusive. Bright and Howard found that CPIcum does tend to be the floor among the various CPI formulas (2:16).

> . . . on the average, the (EAC) technique based upon the most recent data dominates (exceeds) over the technique based upon less recent data (2:16).

Fleming suggests the SCIcum as a ceiling among commonly used EAC formulas included in popular EAC software packages.

> . . . We at Micro-Frame consider this (CPI*SPI) to be a high end formula . . . (9:9)

Finally, the Beach Report provides anecdotal support for the reasonableness of the CPIcum floor and SCIcum ceiling based upon the cancelled A-12 program.

These representative studies illustrate the general conclusions and weaknesses of the EAC research conducted over the past 20 years. While some formulas tend to be preferred, McKinney reviewed EAC research in 1992 and found a lack of consensus remains regarding the appropriateness of the available formulas and formula types (14:76-79).

Recall from Chapter One that the first investigative question asked the following:

1. Which EAC is the most accurate predictor of final Cost at Completion?

As indicated in the review of EAC research to date, there is no one EAC singled out as the most accurate. The CPI, SPI and SCI-based EACs are most often used to estimate program costs but there is no clear pattern of conditions under which each index is most appropriate.

The small and homogeneous databases upon which the comparisons are based present a significant shortcoming. The small sample sizes reduce the certainty of statistical conclusions and inhibit the ability to generalize results. What is missing is a comprehensive test of EAC formulas on

a large, heterogeneous database to better ascertain the validity of EAC formulas.

Our research is designed to address this limitation by performing analysis of EAC models based upon programs in the DAES database. This database provides larger sample sizes from a more complete and diverse set of program data than previously available to those undertaking EAC research.

The methodology for testing the hypothesis and answering the remaining investigative questions is presented in the following chapter.

III. Methodology

This chapter describes the procedures used to test the hypothesis.

H_0: Cost at Completion is bounded below by the CPI-based EAC and above by the SCI-based EAC.

Introduction

Before discussing the methodology applied to test the hypothesis, the database itself merits attention. A description of the database and its fields is followed by an explanation of the process used to prepare the database for use (referred to as data definition). The data description and data definition are followed by an explanation and justification of the approach used to test the hypothesis and an explanation of the actual EAC calculations and graph preparations for data analysis.

The Database

A sample of 321 contracts from the DAES database was selected for analysis to test the hypothesis. The original database contains approximately 500 contracts and 16,000 quarterly report dates of information. The database has various Department of Defense contracts which

date from November, 1972 to October, 1992. The fields of interest for testing the hypothesis include descriptive and numeric fields as described below.

Descriptive Fields

1. Project Number (PNO). This identifies a group of contracts that belong to a particular weapon system program.

2. Contract Number (CNO). This, in conjunction with its corresponding PNO, uniquely identifies each of the 321 contracts used in the DAES database.

3. Submit Date. This, in conjunction with its corresponding PNO and CNO, uniquely identifies each of the 3803 records used in the database. The submit date is important for interpolating missing data.

4. Phase. This identifies the phase as either Pre-Production (PREP), Production (PROD) or Other (OTHER).

5. Contract Type (CTYPE). This identifies the type of contract as Cost Plus (CP), Firm Fixed (FF) or Fixed Price (FP).

6. Branch of Service (SERVICE). This identifies the branch of service initiating the contract: Air Force (F), Army (A), or Navy (N).

7. System Type. This identifies the contract by the type of system: Airframe (A), Electronics (E), Engine (N),

Equipment (Q), Ground (G), Missile (M), Ship (S), Space (P), or Other (OTHER).

8. Over Target Baseline Date (OTB DATE). This field identifies contracts without an OTB date (S) and contracts whose budget baselines went Over Target (in which case the appropriate date is recorded instead of an "S").

Table 2 displays contract categories, their sample sizes and basic descriptive statistics (mean and standard deviation) of the Cost at Completion and Total Allocated Budget for each category.

Numeric Fields

The numeric fields of interest in the database include ACWP, BCWP, BCWS, TAB and MR, as defined in Appendix A. Other numeric fields of interest, as well as the index and EAC calculations, are all computed from these basic fields.

TABLE 2

CONTRACT COMPOSITION BY CATEGORY

Category	No. of Contracts	No. of Reports	CAC[1] (Mean, SD)	TAB[2] (Mean, SD)
All Contracts	321	3803	(316,466)	(292,466)
<u>Phase</u>				
Pre-Production	112	1454	(385,596)	(347,570)
Production	135	1398	(304,418)	(284,294)
Others	74	951		
<u>Contract Type</u>				
Cost Plus	137	709	(297,514)	(276,499)
Firm Fixed	13	96	(215,127)	(220,127)
Fixed Price	169	2053	(337,434)	(310,410)
Other[3]	2	945		
<u>Branch of Service</u>				
Air Force	127	1638	(331,365)	(306,345)
Army	48	606	(214,276)	(173,236)
Navy	144	1524	(346,601)	(331,582)
Other[3]	2	35		
<u>System Type</u>				
Airframe	22	228	(792,732)	(753,684)
Electronics	43	540	(227,234)	(212,217)
Engine	12	117	(183,175)	(184,177)
Equipment	19	212	(205,259)	(195,230)
Ground	8	86	(74,70)	(54,50)
Missile	43	515	(476,763)	(446,746)
Ship	19	244	(610,719)	(567,692)
Space	25	339	(287,285)	(219,214)
Other[3]	130	1522		
<u>Stability Status</u>				
Stable	253	3551	(319,470)	(296,451)
Unstable	68	252	(274,404)	(246,369)

1 CAC refers to Cost at Completion. This is the final ACWP in each contract.

2 TAB refers to Total Allocated Budget.

3 Other refers to contracts that did not clearly fall into the appropriate sensitivity categories. They were therefore excluded from these categorical analyses and summary statistics for "Other" were not pertinent.

Data Definition

One of the first steps involved querying the original database for records with zero values to delete these from consideration. There also were several contracts with fewer than five report dates of information which were removed from consideration. Finally, those contracts which did not contain data from 20 to 80 percent complete were removed from the database. These initial criteria eliminated contracts which lacked data characteristics necessary to test the hypothesis. This resulted in a usable database of 321 contracts with varying numbers of report dates, for a total of 3803 DAES reports of information. Once the usable data was extracted, it was necessary to identify logical categories for comparison in the analysis.

Defining descriptive field entries required queries that searched for a particular entry or set of entries and changed those entries to a desired character. The field identifying Service needed no adjustments. The Contract Types had approximately 25 different versions which were all defined as one of four categories (CP, FF, FP, or OTHER). Phases were all defined as Pre-Production or Production. System Types were derived from a field called Contract Description (CDES). From a list of several hundred descriptions, each entry was assigned one of the eight categories identified above (or OTHER, where the

system fit none of the eight identified categories). Finally, OTB was adjusted to contain an "S" for contracts which did not contain OTB dates. Upon completion of data definition, it was necessary to address the problem of missing data through a process of interpolation. The interpolation process is described in detail in Appendix B.

Having described the database composition and the process used to prepare the database for analysis, the focus turns to an overview, an explanation and a justification of the approach to test the hypothesis.

Overview of Hypothesis Test

There were three EAC values chosen to test the hypothesis. These included the CPI-based EAC, the SPI-based EAC and the SCI-based EAC, all of which are defined in Chapter Two. These three EAC formulas were normalized into percent deviation from CAC. The EAC with the lowest average percent deviation from CAC was defined as the floor while the EAC with the highest average percent deviation from CAC was defined as the ceiling.

The range of ceiling and floor was evaluated to determine if the CAC was bounded by them. If zero average percent deviation from CAC fell within the range of the ceiling and floor, then it was logical to conclude that, on average, CAC was bounded by the ceiling and floor. The

EAC whose average percent deviation from the CAC was closest to zero was defined as the most accurate predictor of the CAC.

Explanation of Approach

The hypothesis was tested with descriptive statistics on the percent deviations from CAC of the three EAC formulas. The mean was the key statistic used. The standard deviation (SD) and coefficient of variation (CV), where CV is the percentage represented by the ratio of SD to the mean, were also calculated to provide additional information about the data dispersion. The Coefficient of Variation was calculated mainly because it provided a measure of relative dispersion across different EAC formulas.

> . . . The standard deviation cannot be the sole basis for comparing two distributions. If we have a standard deviation of 10 and a mean of 5, the values vary by an amount twice as large as the mean itself. If, on the other hand, we have a standard deviation of 10 and a mean of 5,000, the variation relative to the mean is insignificant. Therefore, we cannot know the dispersion of a set of data until we know the standard deviation, the mean, and how the standard deviation compares to the mean. The coefficient of variation ((SD/Mean)*100) is one such relative measure of dispersion . . . (12: 130)

If the CVs differ significantly among EAC formulas, this would indicate that some EACs have wide data dispersion while others have relatively narrower data dispersion. If

two EACs have equal means, then the EAC with the smaller CV (narrower data dispersion) would probably be a more reliable predictor of CAC than the EAC with the larger EAC.

Justification for Approach

Due to data dependence, both across EAC values and down through report dates, it was inappropriate to do a t-test on the difference between EAC means to confirm statistical differences among the means. However, the mean provides the best available measure of central tendancy to compare the EAC formulas.

Testing the Hypothesis

The three EACs evaluated were based on the CPI, SPI and SCI. Three Index Types for each of these indexes were evaluated (cumulative, six-month and three-month) for a total of nine EAC formulas.

Index and EAC Calculations

Each of the nine indexes and EACs was calculated for each of the 3803 DAES report dates. The cumulative calculations used the actual report data values.

The three-month indexes used the three most recent months of report data.

Example Calculation of Three-Month Indexes

CPI3 = (BCWP+BCWP1+BCWP2)/(ACWP+ACWP1+ACWP2)

The six-month indexes used the six most recent months of data.

Example Calculation of Six-Month Indexes

CPI6 =(BCWP+BCWP1+...BCWP5)/(ACWP+ACWP1+...+ACWP5)

The EACs were calculated using their corresponding indexes. The nine EACs are defined as follows.

$$EAC1 = ACWP + (TAB - BCWP)/CPIcum \quad (14)$$

$$EAC2 = ACWP + (TAB - BCWP)/CPI6 \quad (15)$$

$$EAC3 = ACWP + (TAB - BCWP)/CPI3 \quad (16)$$

$$EAC4 = ACWP + (TAB - BCWP)/SPIcum \quad (17)$$

$$EAC5 = ACWP + (TAB - BCWP)/SPI6 \quad (18)$$

$$EAC6 = ACWP + (TAB - BCWP)/SPI3 \quad (19)$$

$$EAC7 = ACWP + (TAB - BCWP)/SCIcum \quad (20)$$

$$EAC8 = ACWP + (TAB - BCWP)/SCI6 \quad (21)$$

$$EAC9 = ACWP + (TAB - BCWP)/SCI3 \quad (22)$$

Upon calculating EAC values, the next step toward testing the hypothesis was to normalize the data for comparison purposes.

Normalizing EAC Values

As defined in Appendix A, Cost at Completion (CAC) was defined to be the final ACWP value in a contract. CAC is necessary to normalize the EAC data into percent deviation from final cost. Failure to normalize the data would cause larger contracts to overshadow the smaller ones. Percent deviation from CAC puts all contracts on level ground for comparative purposes and is calculated as follows.

$$\text{Percent Deviation from CAC} = ((EAC - CAC)/CAC) * 100 \quad (23)$$

These percent deviations were analyzed in testing the hypothesis. With the data normalized, the descriptive statistics were the next calculations of interest.

Descriptive Statistics

The mean, standard deviation and coefficient of variation for all nine EACs were calculated for Overall and for three Contract Completion Stages, defined by Percent Complete (PC) as follows:

Early: $PC \le .35$

Middle: $.35 < PC \le .70$

Late: $PC > .70$

The cutoff points of 35 and 70 percent were chosen to divide the data roughly into thirds to allow for generalizations based upon the Contract Completion Stage.

These were made for five categories (Phase, Contract Type, Service, System Type and Major Baseline Changes). The means were compared to determine the floor (minimum average) and the ceiling (maximum average) for each stage of completion within each category and overall. In addition to determining the ceiling and floor, it was necessary to determine if the CAC fell within the ceiling and floor.

The CAC was bounded by the ceiling and floor only if the ceiling had an average percent deviation from the CAC that was greater than zero and the floor had an average percent deviation from the CAC that was less than zero. (Since an average deviation from the CAC of zero represents the CAC itself, it can only be bounded by the ceiling and floor if zero falls between the ceiling and floor.) This general approach applied to answering the remaining investigative questions.

The following portion of this methodology explains the procedures used to answer investigative questions two through six. In addition to explaining how these questions are answered, a brief description is provided of how graphs were prepared to provide additional information for analysis of trends in the data.

Investigative Questions

2. Of the index-based EACs compared, is the CPI-based EAC the floor and is the SCI-based EAC the ceiling?

This question was answered using two procedures. The first was to calculate the average percent deviation from the Cost at Completion (CAC) for each EAC. This step normalized the data to prevent more costly contracts from shadowing the effects of less costly contracts. These average percent deviations from the CAC were compared to determine the maximum and the minimum average percent deviation from the CAC. The minimum value was the floor and the maximum value was the ceiling.

3. Does the final Cost at Completion lie within the considered range of EACs?

This question was answered by comparing the minimum average percent deviation from the CAC to the maximum average percent deviation from the CAC. The CAC was within the range of EACs only if the minimum average percent deviation from the CAC was less than zero and the maximum average percent deviation from the CAC was greater than zero. As long as the EAC floor was less than the CAC and the EAC ceiling was greater than the CAC, the CAC was within the range of EACs.

4. Which EAC is the most accurate predictor of final Cost at Completion?

The most accurate predictor of final Cost at Completion was defined as the EAC closest to the CAC. In the case where both the ceiling and floor underestimated the CAC, the most accurate predictor of the CAC was the ceiling. In the case where both the ceiling and floor overestimated the CAC, the floor was the most accurate predictor of the CAC. When the CAC was bounded by the ceiling and floor, it was possible for any of the three EACs to be the most accurate predictor of the CAC.

5. Are the original hypothesis test results (answers to questions two through four) sensitive to:

a. Index Type (Cumulative, Six-Month or Three-Month)

This question was answered by comparing the three cumulative index-based EACs (EAC1, EAC4 and EAC7), the three six-month index-based EACs (EAC2, EAC5 and EAC8) and the three three-month index-based EACs (EAC3, EAC6 and EAC9). In all three cases, if the maximum and minimum average percent deviation from the CAC remained the same, if the position of the CAC relative to the floor and ceiling remained the same, and if the same EAC was the most accurate predictor of the CAC, then the original results were not sensitive to the Index Type.

b. Program Phase (Pre-Production or Production)

This question was answered by determining the EAC minimum and maximum average percent deviations from the CAC for both the Pre-Production and the Production contracts. If the results were the same as the original results, if the position of the CAC relative to the floor and ceiling remained the same, and if the same EAC was the most accurate predictor of the CAC, then the results were not sensitive to Program Phase.

c. Contract Type (Cost Plus, Firm Fixed or Fixed Price)

This question was answered by determining the minimum and the maximum average percent deviation from the CAC for each Contract Type (Cost Plus, Firm Fixed and Fixed Price). There were some contracts in the database which contained combinations of these Contract Types. Those contracts which contained more than one Contract Type and those contracts whose Contract Type could not be identified were not included in this sensitivity analysis. If the results agreed with the original results, if the position of the CAC relative to the ceiling and floor remained the same, and if the same EAC was the most accurate predictor of the CAC, then the results were not sensitive to Contract Type.

d. Service (Army, Navy or USAF)

This sensitivity was tested by determining the minimum and maximum average percent deviation from the CAC for each Branch of Service. If the results agreed with the original results, if the position of the CAC relative to the ceiling and floor remained the same, and if the same EAC was the most accurate predictor of the CAC, then the results were not sensitive to Service.

e. System Type (Airframe, Electronics, Engine, Equipment, Ground, Missile, Ship or Space)

This sensitivity was tested by determining the minimum and maximum average percent deviations from the CAC for each System Type. If the results agreed with the original results, if the position of the CAC relative to the ceiling and floor remained the same, and if the same EAC was the most accurate predictor of the CAC, then the results were not sensitive to System Type.

f. Major Baseline Changes (Not OTB or OTB)

This sensitivity was tested by determining the minimum and maximum average percent deviations from the CAC for those contracts which went Over the Target Baseline (OTB) and those that did not go Over the Target Baseline (NOT OTB). If the results agreed with the original results, if the position of the CAC relative to

the ceiling and floor remained the same, and if the same EAC was the most accurate predictor of the CAC, then the results were not sensitive to Major Baseline Changes.

g. Management Reserve

This sensitivity was tested on all contracts where Management Reserve (MR) represented less than 30 percent of Total Allocated Budget (TAB). MR should only be a small portion of TAB. If MR is greater than 30 percent of TAB, then the MR data is probably incorrect and should not be used in the analysis. This restriction provided 239 contracts and 3508 DAES reports with which to test the sensitivity. The calculations involved subtracting MR from TAB to arrive at Budget at Completion (BAC). BAC then replaced TAB in the basic EAC equation. The minimum and maximum EAC average percent deviations from the CAC were determined, as well as the relative position of the CAC to the minimum and maximum. Additionally, the EAC with the average percent deviation from the CAC closest to zero was the most accurate predictor of CAC. If the results agreed with the original results, if the position of the CAC relative to the ceiling and floor remained the same, and if the same EAC was the most accurate predictor of the CAC, then the results were nct sensitive to Management Reserve.

6. Are the original results and the results in each category sensitive to the Contract Completion Stage?

This question was answered by considering the contracts in each category during the three previously defined Contract Completion Stages. For example, the contracts that were Pre-Production were analyzed at Early, Middle and Late Contract Completion Stages. For each completion stage, there was an EAC floor, an EAC ceiling and an EAC which was the most accurate predictor of the CAC. If the results based on Early, Middle and Late Contract Completion Stages agreed with the original results, then the Pre-Production category was not sensitive to the Contract Completion Stage.

The methodologies outlined for the investigative questions two through four provided the means to determine the original hypothesis test results. The methodologies for investigative questions five and six provided a way to evaluate sensitivity of the original results to Index Type, Program Phase, Contract Type, Service, System Type, Major Baseline Changes, Management Reserve and Contract Completion Stage.

The results to these five remaining investigative questions are presented in the following chapter.

Summary

This chapter reintroduced the hypothesis and describes the database used to test the hypothesis. The process used to prepare the database for use included reference to the descriptive fields and the numeric fields used for the analysis. An overview of the hypothesis test provided an explanation of the technique used to evaluate the hypothesis and sensitivity to the various conditions, as described in the five remaining investigative questions.

The equations for the nine indexes and EACs were provided, followed by a description of the methodology applied to answer each of the five remaining investigative questions.

The following chapter focuses on the results of the hypothesis test. It presents the results to the five remaining investigative questions. Graphs of the overall results are provided with comments and analysis.

IV. Results

This chapter focuses on the results of the methodology. The hypothesis is restated and the results are presented. The final five Investigative Questions are answered, followed by a description of trends noticed in the graphs of the EAC ceiling and floor for each category of contracts.

Hypothesis

The hypothesis, as stated previously, is the following:

Ho: The Cost at Completion is bounded below by the CPI-based EAC and above by the SCI-based EAC.

Recall from the methodology that several investigative questions were posed to test the hypothesis. These questions are answered in the following section.

The results to the hypothesis test and the sensitivity analysis are presented in Table 3. Results to Contract Completion Stage sensitivity are presented in Table 4 and Table 5. The graphs of the EAC ceiling and floor and the corresponding index graphs for each category are presented in Appendix D.

TABLE 3

HYPOTHESIS TEST RESULTS BY CATEGORY

Contract Category (# of contracts, # of reports)[2]		Range of Index-Based EACs [1]			
		Min	Max	Bounds CAC?[3]	Closest to CAC[4]
All	Contracts Taken as a Whole (321, 3803)	CPI	SCI	NO	SCI
Program Phase	Pre-Production (112, 1454)	CPI	SCI	NO	SCI
	Production (135, 1398)	CPI	SCI	YES	SPI
Contract Type	Cost Plus (137, 1630)	CPI	SCI	NO	SCI
	Firm Fixed (13, 96)	CPI	SCI	NO	CPI
	Fixed Price (169, 2053)	CPI	SCI	YES	SCI
Branch of Service	Army (48, 606)	CPI	SCI	NO	SCI
	Navy (144, 1424)	SPI	SCI	NO	SPI
	USAF (127, 1638)	CPI	SCI	NO	SCI
System Type	Airframe (22, 228)	SPI	SCI	NO	SCI
	Electronics (43, 540)	CPI	SCI	NO	SCI
	Engine (12, 117)	CPI	SCI	NO	CPI
	Equipment (19, 213)	CPI	SCI	NO	SCI
	Ground (8, 86)	CPI	SCI	NO	CPI
	Missiles (43, 315)	CPI	SCI	NO	SCI
	Ships (19, 244)	SPI	SCI	NO	SPI
	Space(25, 339)	CPI	SCI	NO	SCI
Major Baseline Changes	Not Over Target Baseline (253, 3551)	CPI	SCI	NO	SCI
	Over Target Baseline (68, 252)	SPI	SCI	NO	SCI

1 EAC=ACWP + (TAB-BCWP)/Index, where index is one of these three indexes:
Cost Performance Index (CPI)=BCWP/ACWP
Schedule Performance Index (SPI)=BCWP/BCWS
Schedule Cost Index (SCI)=CPI*SPI

2 # of reports refers to the sample size of DAES quarterly report data. Reports are a subset of contracts. The sum of contract subcategories is less than the total number of contracts because some fields in the database were empty for some contracts.

3 Does the range of index-based EACs evaluated bound CAC? CAC refers to Cost at Completion, defined as the final ACWP in each contract. If the MIN EAC is lower than CAC and if the MAX EAC is higher than CAC, then the answer is YES.

4 The EAC closest to the CAC is the most accurate predictor of CAC.

TABLE 4

CONTRACT COMPLETION STAGE SENSITIVITY BY CATEGORY

Contract Category		Range of Index-Based EACs[1]			
	Completion Stage[2] (# of contracts, # of reports)[3]	Min	Max	Bounds CAC?[4]	Closest to CAC[5]
All	Contracts Taken as a Whole				
	Early (321, 302)	CPI	SCI	NO	SCI
	Middle (321, 1073)	CPI	SCI	NO	SCI
	Late (321, 2428)	SPI	SCI	NO	SPI
Program Phase	Pre-Production				
	Early (112, 100)	CPI	SCI	NO	SCI
	Middle (112, 406)	CPI	SCI	NO	SCI
	Late (112, 948)	SPI	SCI	NO	SPI
	Production				
	Early (135, 113)	CPI	SCI	NO	SCI
	Middle (135, 354)	CPI	SCI	NO	SCI
	Late (135, 931)	SPI	SCI	NO	SPI
Contract Type	Cost Plus				
	Early (137, 90)	CPI	SCI	NO	SCI
	Middle (137,466)	CPI	SCI	NO	SCI
	Late (137, 1074)	SPI	SCI	YES	SCI
	Firm Fixed				
	Early (13, 5)	SPI	SCI	NO	SPI
	Middle (13, 25)	CPI	SPI	NO	CPI
	Late (13, 66)	CPI	SPI	NO	CPI
	Fixed Price				
	Early (169, 2053)	CPI	SCI	NO	SCI
	Middle (169, 195)	CPI	SCI	NO	SCI
	Late (169, 578)	CPI	SCI	NO	CPI
Branch of Service	Army				
	Early (48, 41)	SPI	SCI	YES	SCI
	Middle (48, 17)	CPI	SCI	NO	SCI
	Late (48, 394)	SPI	SCI	NO	SCI
	Navy				
	Early (144, 112)	SPI	SCI	NO	SCI
	Middle (144, 411)	SPI	SCI	NO	SCI
	Late (144, 1001)	SPI	SCI	NO	SPI
	USAF				
	Early (127, 148)	CPI	SCI	NO	SCI
	Middle (127, 471)	CPI	SCI	NO	SCI
	Late (127, 1019)	SPI	SCI	NO	SPI
Major Baseline Changes	Not Over Target Baseline				
	Early (253, 272)	CPI	SCI	NO	SCI
	Middle (253, 993)	CPI	SCI	NO	SCI
	Late (253, 2286)	SPI	SCI	NO	SPI
	Over Target Baseline				
	Early (68, 30)	CPI	SCI	YES	SPI
	Middle (68, 80)	SPI	SCI	NO	SCI
	Late (68, 142)	SPI	SCI	NO	SCI

TABLE 4 (Continued)

CONTRACT COMPLETION STAGE SENSITIVITY BY CATEGORY

1 EAC=ACWP + (TAB-BCWP)/Index, where index is one of these three indexes:
   Cost Performance Index (CPI)=BCWP/ACWP
   Schedule Performance Index (SPI)=BCWP/BCWS
   Schedule Cost Index (SCI)=CPI*SPI

2 Completion Stage refers to Percent Complete (PC) where PC=BCWP/TAB.
   Early: PC<=.35
   Middle: .35<PC<=.70
   Late: PC>.70

3 # of reports refers to the sample size of DAES quarterly report data. Reports are a subset of contracts. The sum of contract subcategories is less than the total number of contracts because some fields in the database were empty for some contracts.

4 Does the range of index-based EACs evaluated bound CAC? CAC refers to Cost at Completion, defined as the final ACWP in each contract. If the MIN EAC is lower than CAC and if the MAX EAC is higher than CAC, then the answer is YES.

5 The EAC closest to the CAC is the most accurate predictor of CAC.

TABLE 5

CONTRACT COMPLETION STAGE SENSITIVITY BY SYSTEM TYPE

System Type	Range of Index-Based EACs [1]			
Completion Stage[2] (# of contracts, # of reports)[3]	**Min**	**Max**	**Bounds CAC?[4]**	**Closest to CAC[5]**
Airframe				
Early (22, 18)	SPI	SCI	NO	SCI
Middle (22, 55)	SPI	SCI	YES	SCI
Late (22, 155)	CPI	SCI	NO	CPI
Electronics				
Early (43, 43)	CPI	SPI	NO	SPI
Middle (43, 160)	CPI	SCI	NO	SCI
Late (43, 337)	CPI	SCI	NO	CPI
Engines				
Early (12, 5)	CPI	SCI	YES	CPI
Middle (12, 31)	CPI	SCI	NO	SCI
Late (12, 81)	SPI	SCI	NO	SPI
Equipment				
Early (19, 22)	CPI	SCI	NO	SCI
Middle (19, 55)	CPI	SCI	NO	SCI
Late (19, 136)	CPI	SCI	NO	CPI
Ground				
Early (8, 7)	CPI	SCI	NO	SCI
Middle (8, 20)	CPI	SCI	NO	SCI
Late (8, 59)	SPI	SCI	NO	SCI
Missiles				
Early (43, 40)	CPI	SCI	NO	SCI
Middle (43, 152)	CPI	SCI	NO	SCI
Late (43, 323)	SPI	SCI	YES	SPI
Ships				
Early (19, 24)	SPI	CPI	NO	CPI
Middle (19, 77)	CPI	SCI	NO	SCI
Late (19, 143)	SPI	SCI	NO	SPI
Space				
Early (25, 31)	CPI	SCI	YES	SCI
Middle (25, 91)	CPI	SCI	NO	SCI
Late (25, 213)	SPI	SCI	NO	SCI

TABLE 5 (Continued)

CONTRACT COMPLETION STAGE SENSITIVITY BY SYSTEM TYPE

1 EAC=ACWP + (TAB-BCWP)/Index, where index is one of these three indexes:
  Cost Performance Index (CPI)=BCWP/ACWP
  Schedule Performance Index (SPI)=BCWP/BCWS
  Schedule Cost Index (SCI)=CPI*SPI

2 Completion Stage refers to Percent Complete (PC) where PC=BCWP/TAB.
  Early: PC<=.35
  Middle: .35<PC<=.70
  Late: PC>.70

3 # of reports refers to the sample size of DAES quarterly report data. Reports are a subset of contracts. The sum of contract subcategories is less than the total number of contracts because some fields in the database were empty for some contracts.

4 Does the range of index-based EACs evaluated bound CAC? CAC refers to Cost at Completion, defined as the final ACWP in each contract. If the MIN EAC is lower than CAC and if the MAX EAC is higher than CAC, then the answer is YES.

5 The EAC closest to the CAC is the most accurate predictor of CAC.

Investigative Questions and Hypothesis Test Results

The first investigative question was answered in Chapter Two with the review of EAC research to date. The remaining questions are answered here. The questions are restated as they appear in Chapter One and Chapter Three, followed by a discussion of the results and an answer to each question.

2. Of the index-based EACs compared, is the CPI-based EAC the floor and is the SCI-based EAC the ceiling?

Of the EACs compared, the CPI-based EAC was the minimum and the SCI-based EAC was the maximum. This confirmed the CPI-based EAC as the floor and the SCI-based EAC as the ceiling for the entire set of contracts.

OVER-ALL FLOOR: CPI-BASED EAC

OVER-ALL CEILING: SCI-BASED EAC

3. Does the final Cost at Completion lie within the considered range of EACs?

The final CAC did not lie within the considered range of EACs. On average, the CAC was slightly higher than the range of EACs.

4. Which EAC is the most accurate predictor of final Cost at Completion?

The SCI-based EAC was the most accurate predictor of the final CAC. On average, the SCI-based EAC underestimated the CAC with an average percent deviation from CAC of -1.01 percent.

5. Are the original hypothesis test results (answers to questions two through four) sensitive to:

a. Index Type (Cumulative, Six-Month or Three-Month) The cumulative CPI-based EAC and the cumulative SCI-based EAC bounded the cumulative SPI-based EAC. The six-month and three-month results had the same EAC rank order as the cumulative results. Since these results for each Index type agreed with the original results, **the original results were not sensitive to the Index Type.**

Another important observation resulted from analysis of the EAC average percent deviations from the CAC according to Index Types. The cumulative CPI, six-month CPI and the three-month CPI all tended to be very close together. Likewise, the cumulative, six-month and three-month values for SPI were close together and the cumulative, six-month and three month SCI values were close together.

As explained in the justification for the methodology in Chapter Three, it was not appropriate to apply a t-test on the significance of the difference between means across

the EACs. However, it did seem apparent by visual inspection that the CPIs are close to each other, SPIs are close to each other and SCIs are close to each other, while the groups of CPIs, SPIs and SCIs all seem to estimate in three distinct groups.

b. Program Phase (Pre-Production or Production)

Both Pre-Production and Production contracts had the same ceiling and floor as the original results. The CAC was bounded by the floor and ceiling for Production contracts only. The most accurate predictor of the CAC for Pre-Production contracts agreed with the original results (SCI-based EAC). The most accurate predictor of the CAC for Production contracts was the SPI-based EAC. These findings indicated that **the original results were sensitive to the Program Phase.**

c. Contract Type (Cost Plus, Firm Fixed or Fixed Price)

The floor and ceiling for all three Contract Types agreed with the original results. The position of the CAC relative to the ceiling and floor differed among the three contract types.

The ceiling and floor for Cost Plus contracts underestimated the CAC and had the SCI-based EAC for the most accurate predictor of the CAC. The ceiling and floor

for Firm Fixed contracts overestimated the CAC and had the CPI-based EAC for the most accurate predictor of the CAC. The ceiling and floor for Fixed Price contracts bounded the CAC and had the SCI-based EAC for the most accurate predictor of CAC. These findings indicated that **the original results were sensitive to the Contract Type.**

d. Service (Army, Navy or USAF)

The results for the Army and USAF contracts agreed with the original results. The Navy results indicated the floor was the SPI-based EAC and the ceiling agreed with the original results. The Navy ceiling and floor both slightly overestimated the CAC and the SPI-based EAC was closest the CAC. These findings indicated that **the original results were sensitive to the Branch of Service.**

e. System Type (Airframe, Electronics, Engine, Equipment, Ground, Missile, Ship or Space)

Results of this sensitivity agreed with the original results, with the following exceptions. The floor for Airframe contracts was the SPI-based EAC. The ceiling and floor bounded the CAC.

The ceiling and floor for both Engines and Equipment agreed with the original findings but they overestimated

the CAC, making the CPI-based EAC the most accurate predictor of CAC.

The floor for Ships was the SPI-based EAC and the ceiling and floor overestimated the CAC, making the SPI-based EAC the most accurate predictor of the CAC. These findings indicated that **the original results were sensitive to the System Type.**

f. Major Baseline Changes (Not OTB or OTB)

The Over Target Baseline contracts had the SPI-based EAC floor. This indicated that **results were sensitive to Major Baseline Changes.**

g. Management Reserve

The results with MR removed from the calculations agreed with the original results, suggesting that **the original results were not sensitive to Management Reserve.**

6. Are the original results and the results in each category sensitive to the Contract Completion Stage? The answers to this question are briefly summarized below and are presented in Table 4 and Table 5.

Original Results: The original results remained the same in the Early and Middle Contract Completion Stages. The SPI-based EAC became the floor in the Late Stage, with

the SPI-based EAC as the most accurate predictor of the CAC. These findings indicate that **the original results were sensitive to the Contract Completion Stage.**

Program Phase: The Pre-Production and Production results differed from the original results in the Late Completion Stage. They had the SPI-based EAC floor and the SPI-based EAC was the most accurate predictor of the CAC in both cases. These results suggest that **Program Phase results were sensitive to the Contract Completion Stage.**

Contract Type: Cost Plus and Firm Fixed Contracts all showed slightly different results across the Early, Middle and Late Completion Stages. Cost Plus had the SPI-based EAC as a floor in the Late Completion Stage while Firm Fixed Contracts had the SPI-based EAC as a floor in the Early Completion Stage. These findings suggest that **Contract Type results were sensitive to the Contract Completion Stage.**

Service: The Army Contracts started with the SPI-based EAC floor and switched to the CPI-based floor in the Middle Completion Stage. Air Force Contracts started with the CPI-based EAC floor then switched to the SPI-based floor in the Late Completion Stage. These findings

suggest that the **Branch of Service results were sensitive to the Contract Completion Stage.**

System Type: The SPI-based EAC was the floor in the Early Completion Stage for Ships and in the Early and Middle Stages for Airframes. The SPI-based EAC was the ceiling for Electronics Contracts in the Early Stage. The CPI-based EAC was the ceiling for Ships in the Early Stage. These results suggest that **System Type results were sensitive to the Contract Completion Stage.**

Major Baseline Changes: The floor for contracts with no major baseline changes (not OTB) was the SPI-based EAC in the Late Completion Stage. The SPI-based EAC was also the floor for OTB contracts in the Middle and Late Completion Stages. These results suggest that **the results based on Major Baseline Changes were sensitive to the Contract Completion Stage.**

In addition to anwering the investigative questions by analyzing the EAC average percent deviations from the Cost at Completion, there were several noteworthy trends apparent in the graphs of the indexes and the EAC average percent deviations from the CAC.

Graphical Analysis of Indexes

The indexes followed a predictable pattern, with the exception of the 50 to 60 percent completion point. There was a pronounced upward spike in SPI and SCI for All Contracts, Production, Fixed Price, Navy and OTB Contracts.

Further analysis revealed one Navy contract which had extremely high SPI values between 50 and 60 percent complete. This one contract caused the upward spike in the SPI and the SCI. This increase in the SPI and the SCI was not large enough to noticeably affect the EAC average percent deviations from the CAC.

Figures 1, 2, 3 and 4 illustrate the overall results. Figures 1 and 2 represent the overall EAC ceiling and floor and the corresponding indexes with this Navy contract included. Figures 3 and 4 represent the same overall results, with this Navy contract removed. Comparison of Figures 1 and 2 to Figures 3 and 4 revealed that this one Navy contract had a significant impact on the graph of the indexes but it did not significantly affect the graph of the EAC ceiling and floor.

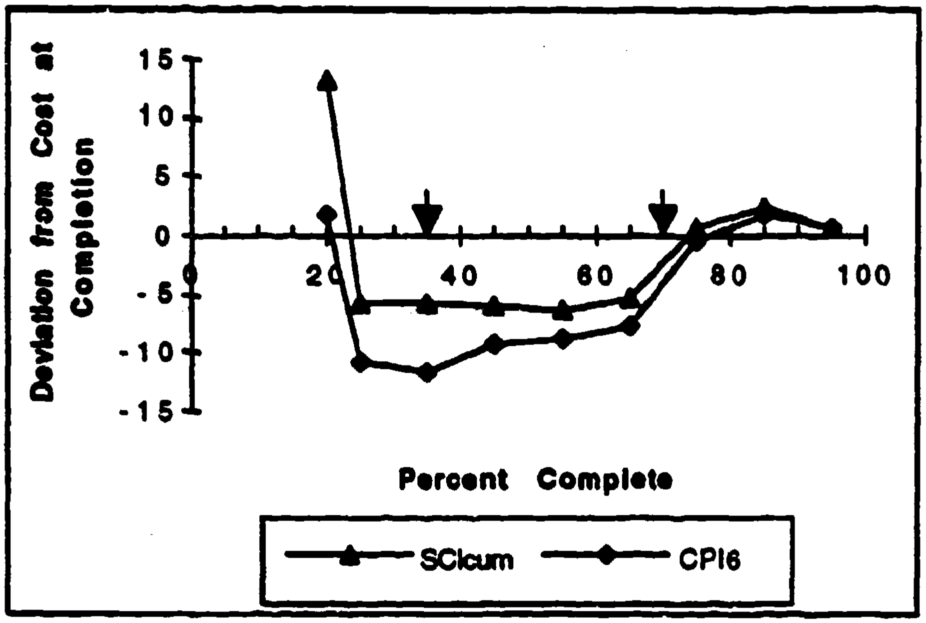


Figure 1. Overall EAC Ceiling and Floor

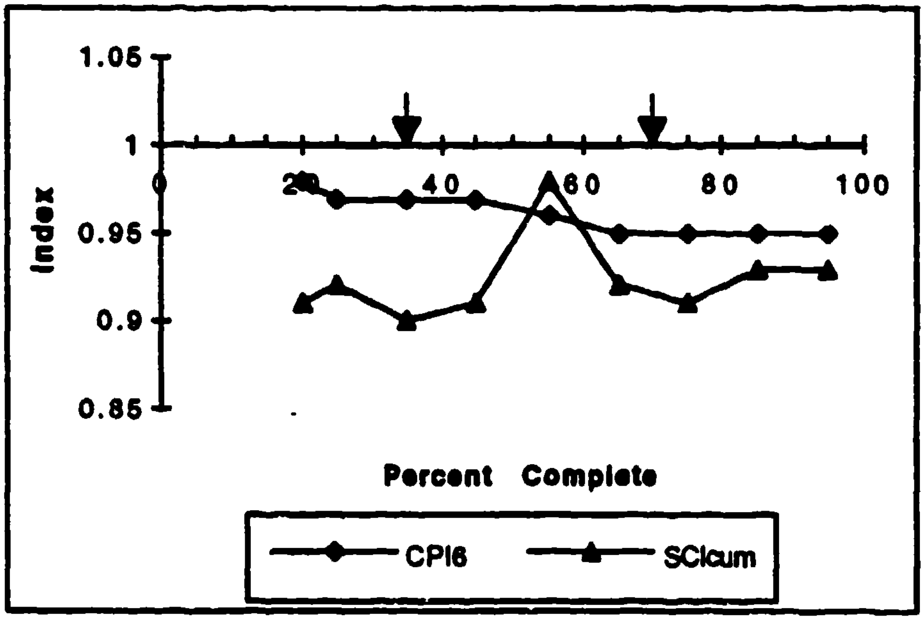


Figure 2. Overall Index Ceiling and Floor

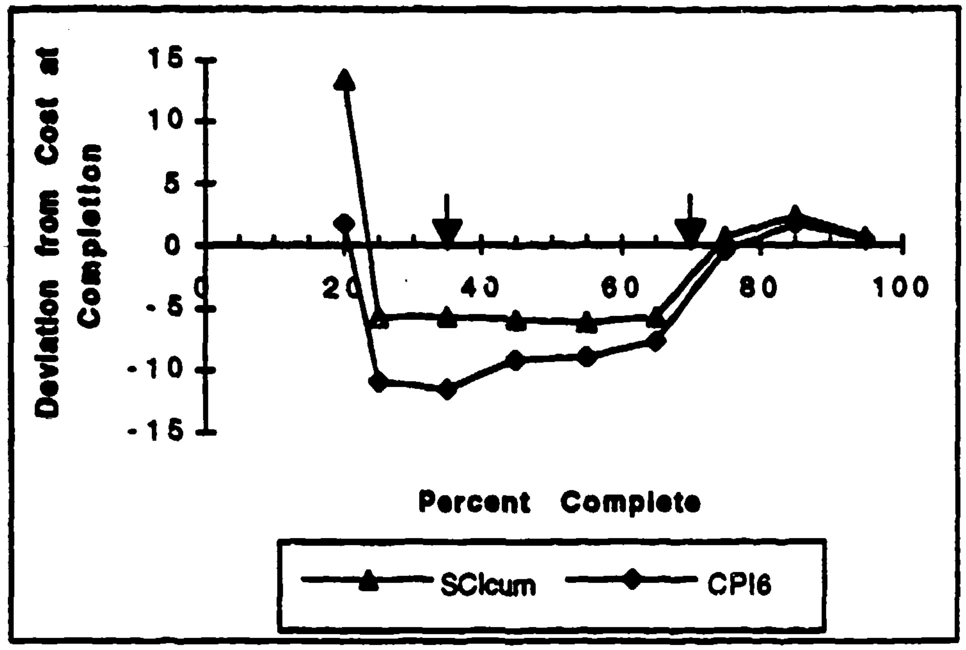


Figure 3. Overall (Navy Contract Removed) EAC Ceiling and Floor

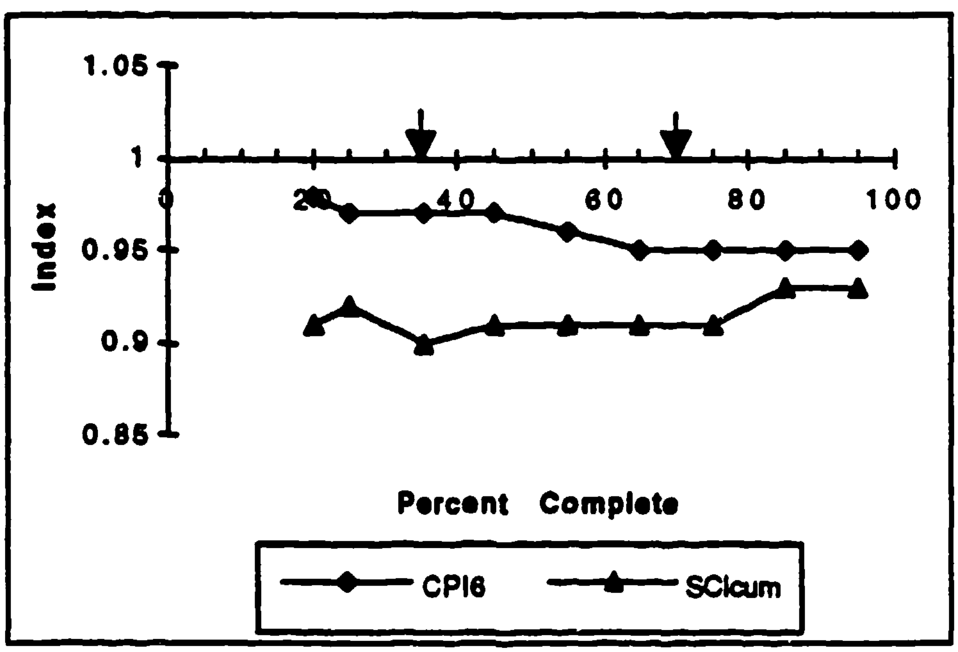


Figure 4. Overall (Navy Contract Removed) Index Ceiling and Floor

Graphical Analysis of EACs

Analysis of the EAC graphs revealed several noteworthy trends among various contract categories, as described below.

1. EACs tended to estimate the CAC quite accurately prior to the 25 percent completion point. Between 25 and 65 percent, the EACs took a fairly pronounced downward dip, then approached the CAC at the 75 percent completion point. The EACs slightly overestimated the CAC between the 75 and 95 percent completion points. This "dipper" effect occured among all the contracts taken as a whole, Pre-Production, Cost Plus, Army, Over Target Baseline and Not Over Target Baseline contracts.

2. Several contract categories estimated fairly close to the CAC throughout the entire contract life. These included Production, Navy, Air Force, and Missile contracts.

3. A few categories overestimated the CAC in the Early Completion Stage, then underestimated the CAC between 35 and 75 percent completion and finished in the Late Stage close to CAC. These included Engines, Equipment and Space contracts.

4. There were also some categories which estimated low in the Early Stage then recovered to estimate close to the CAC in the Middle and Late Stages. This trend occured in Airframe, Electronics and Ship contracts.

5. Firm Fixed contracts tended to overestimate the CAC throughout the entire contract, while Fixed Price contracts tended to underestimate the CAC.

<u>Summary</u>

This chapter answered the remaining investigative questions and presented results of the hypothesis test. Overall, the CPI-based EAC and the SCI-based EAC were confirmed as the boundaries to the range of EACs. The SCI-based EAC was confirmed as the most accurate predictor of the Cost at Completion. These overall results were not sensitive to Index Type (cumulative, six-month or three-month) or Management Reserve. The results were sensitive to Program Phase, Contract Type, Branch of Service, System Type and Major Baseline Changes.

Having provided the results of the hypothesis, the final chapter discusses these results and their significance to program managers. Areas for future related research follow this discussion.

V. Discussion

This chapter summarizes the research by reviewing the hypothesis and restating the conclusions and implications for program managers. The discussion recaps the data analysis followed by recommendations for further research.

Review of the Hypothesis

This thesis explored the hypothesis that the Cost at Completion (CAC) is bounded below by the CPI-based Estimate at Completion (EAC) and above by the SCI-based EAC. The hypothesis was tested on 321 contracts. Descriptive statistics provided a method for testing the hypothesis. Additional information resulted from analyzing trends in graphs of the range of EACs by category.

Conclusion

Of the EACs evaluated, the CPI-based EAC was confirmed as the floor and the SCI-based EAC was confirmed as the ceiling. On average, the range of EACs tended to slightly underestimate the CAC, thus the CAC was not bounded by the range of EACs as hypothesized. The SCI, on average, was the most accurate predictor of the CAC.

The results were tested for sensitivity to Index Type (cumulative, six-month and three-month), Contract

Completion Stage, Program Phase, Contract Type, Branch of Service, System Type, Major Contract Baseline Changes and Management Reserve. The results were sensitive to all of these conditions except Management Reserve. With Management Reserve removed from the calculations, the results agreed with the original results.

Analysis of Results

The hypothesis test methodology consisted of analyzing descriptive statistics of the DAES database. The mean was the key statistic used and the standard deviation and coefficient of variation were also calculated to provide information on data dispersion for each of nine EACs over 3803 DAES reports of information.

The values for three and six month indexes were interpolated from existing data for each of the DAES reports. This was accomplished with a script written in Paradox® Application Language (PAL), presented in Appendix B.

Upon completion of interpolating needed values for three and six month indexes, the EACs were calculated for each of the 3803 DAES reports.

The resulting EACs were normalized into percent deviations from the CAC. These percentages were then averaged over early, middle, late and overall stages of completion. Additionally, the standard deviations and

coefficients of variation were calculated over these stages.

The EAC with the lowest average percent deviation from the CAC was defined as the floor and the EAC with the highest average percent deviation from the CAC was defined as the ceiling. The CAC was defined to be bounded by the floor and ceiling if the floor was less than the CAC and the ceiling was greater than the CAC.

The results show that on average, the EACs are bounded below by the CPI-based EAC and above by the SCI-based EAC. Because the range of EACs tended to underestimate the CAC, the CAC was not bounded by the floor and ceiling. However, it is important to note that for the contracts overall, the range of EACs had an average percent deviation from the CAC of less than five percent. This made the CPI, SPI and SCI-based EACs very close predictors of the CAC, despite the fact that the CAC was not actually bounded by them.

Analysis of the EACs over different contract completion stages by category resulted in EAC average percent deviations from the CAC which ranged from -17 percent to +30 percent. In addition to the range, an important observation involved the groupings of each index.

The CPIs were fairly close to each other, the SPIs were fairly close to each other and the SCIs were fairly

close to each other. This had important implications. Although the six-month CPI-based EAC was the actual EAC floor, it differed from the cumulative CPI-based EAC by less than one percent average deviation from the CAC.

This made the cumulative CPI-based EAC a very close approximation of the floor for EACs. The cumulative CPI is much easier to ascertain from report data because it requires only current information. The three and six-month EACs require several consecutive months of previous report data, which may not always be available.

The bottom line for program managers is that the cumulative CPI-based EAC and the cumulative SCI-based EACs are very close approximations of the floor and ceiling for EAC formulas. Overall, the actual CAC, on average, is not bounded by the range of EACs. The SCI-based EAC is the most accurate predictor of the CAC.

The graphs of the EAC ceiling and floor for each category show the program managers how the range of EACs relates to the actual Cost at Completion. These graphs should help program analysts predict reasonable completion costs for different categories of contracts.

For example, an analyst working on a missile contract estimate could refer to Figure 5 the graph for Missile Contracts. If the contract was in the Early Completion Stage, the analyst would know that the SCI-based EAC would provide the most accurate predictor of the final Cost at

Completion. The analyst would also know that an estimate lower than the CPI-based EAC would be overly optimistic.

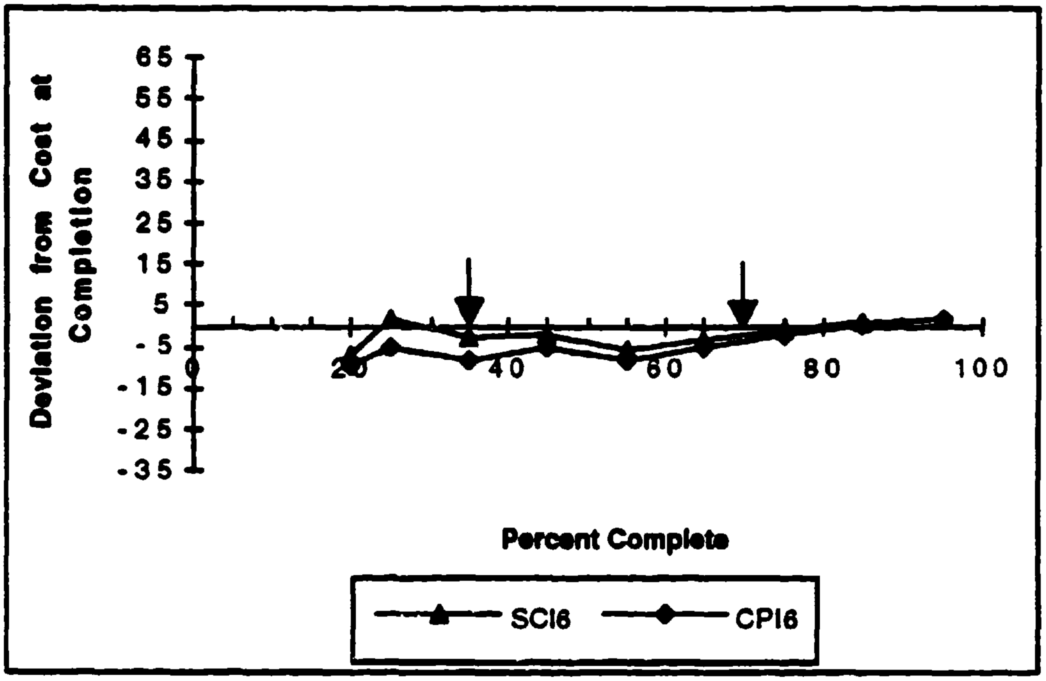


Figure 5. Missile EAC Ceiling and Floor

The arrows on the horizontal axis (X axis-Percent Complete) represent transition points between Early, Middle and Late Contract Completion Stages. Specifically:

Early: Contract Percent Complete < .35
Middle: .35 < Contract Percent Complete <= .70
Late: Contract Percent Complete > .70

Areas for Future Research

One limitation of this research effort is that the Management Reserve sensitivity analysis was not extended to the individual categories at early, middle and late stages of completion to see if eliminating MR might have made a difference in one or more of these isolated circumstances.

Additional sensitivity analysis might also prove useful by further stratifying the categories. For example, a program manager might wish to make inferences about a Missile program which is Pre-Production and Cost Plus. Further sensitivity analysis on putting the data into constant dollars by eliminating inflation from the data would strengthen the final results.

Finally, a more detailed statistical analysis of the DAES database would be very useful for future research.

Appendix A: Cost/Schedule Control Systems Criteria Definitions

This Appendix presents photocopied pages from DOD 5000.2-M displaying official C/SCSC definitions of terms used in this thesis. Also presented are definitions of terms not included in DOD 5000.2-M but relevent to this research effort.

COST/SCHEDULE CONTROL SYSTEMS DEFINITIONS

1. Actual Cost of Work Performed (ACWP). The cost incurred and recorded in accomplishing the work performed within a given time period.

2. Actual Direct Costs. Those costs identified specifically with a contract, based upon the contractor's cost identification and accumulation system as accepted by the cognizant Defense Contract Audit Agency representatives. (See definition 14, below.)

3. Allocated Budget. (See definition 32, below.)

4. Applied Direct Cost. The amount recognized in the time period associated with the consumption of labor, material, and other direct resources, without regard to the date of commitment or the date of payment. These amounts are to be charged to work-in-progress in the time period that any one of the following occurs:

   a. When labor, material, and other direct resources are actually consumed.

   b. When material resources are withdrawn from inventory for use.

   c. When material resources are received that are identified uniquely to the contract and scheduled for use within 60 days.

   d. When major components or assemblies are received on a line flow basis that are identified specifically and uniquely to a single serially numbered end item.

5. Apportioned Effort. Effort that is not readily divisible into work packages, but is related proportionately to measured effort.

6. Authorized Work. Effort that has been definitized and is on contract, plus that for which definitized contract costs have not been agreed to, but for which written authorization has been received.

7. Baseline. (See definition 24, below.)

8. Budgeted Cost for Work Performed (BCWP). The sum of the budgets for completed work packages and completed portions of open work packages, plus the applicable portion of the budgets for level of effort and apportioned effort.

9. Budgeted Cost for Work Scheduled (BCWS). The sum of budgets for all work packages, planning packages, etc., scheduled to be accomplished (including in-process work packages), plus the amount of level-of-effort

and apportioned effort scheduled to be accomplished within a given time period.

10. Budgets for Work Packages. (See definition 36, below.)

11. Contract Budget Base. The negotiated contract cost plus the estimated cost of authorized unpriced work.

12. Contractor. An entity in private industry which enters into contracts with the Government. In this Instruction, the word also may apply to Government-owned, Government-operated activities that perform work on defense programs.

13. Cost Account. A management control point at which actual costs may be accumulated and compared to the budgeted cost of the work performed. A cost account is a natural control point for cost/schedule planning and control, since it represents the work assigned to one responsible organizational element on one contract work breakdown structure element.

14. Direct Costs. Any costs that may be identified specifically with a particular final cost objective. This term is explained in the Federal Acquisition Regulation (reference (f)).

15. Estimate at Completion (EAC). Actual direct costs, plus indirect costs allocable to the contract, plus estimate of costs (direct and indirect) for authorized work remaining.

16. Indirect costs. Costs, which because of their incurrence for common or joint objectives, are not subject readily to treatment as direct costs. This term is further defined in the Federal Acquisition Regulation (reference (f)).

17. Initial Budget. (See definition 22, below.)

18. Internal Replanning. Replanning actions performed by the contractor for remaining effort within the recognized total allocated budget.

19. Level-of-Effort (LOE). Effort of a general or supportive nature that does not produce definite end products.

20. Management Reserve or Management Reserve Budget. An amount of the total allocated budget withheld for management control purposes, rather than designated for the accomplishment of a specific task or set of tasks. It is not a part of the performance measurement baseline.

21. Negotiated Contract Cost. The estimated cost negotiated in a cost plus fixed fee contract, or the negotiated contract target cost in either a fixed price incentive contract or a cost plus incentive fee contract.

22. Original Budget. The budget established at, or near, the time that the contract was signed and based on the negotiated contract cost.

23. Overhead. (See definition 16, above.)

24. Performance Measurement Baseline. The time phased budget plan against which contract performance is measured. It is formed by the budgets assigned to scheduled cost accounts and the applicable indirect budgets. For future effort, not planned to the cost account level, the performance measurement baseline also includes budgets assigned to higher level contract work breakdown structure elements and undistributed budgets. It equals the total allocated budget less management reserve.

25. Performing Organization. A defined unit within the contractor's organizational structure, which applies the resources to perform the work.

26. Planning Package. A logical aggregation of far term work within a cost account which may be identified and budgeted in early baseline planning, but is not yet defined into work packages.

27. Procuring Activity. The subordinate command in which the Procurement Contracting Officer is located. It may include the program office, related functional support offices, and procurement offices. Examples of procuring activities are the Army Missile Command, Naval Sea Systems Command, and Air Force Electronic Systems Division.

28. Replanning. (See definition 18, above.)

29. Reprogramming. Replanning of the effort remaining in the contract, resulting in a new budget allocation that exceeds the contract budget base.

30. Responsible Organization. A defined unit within the contractor's organizational structure that is assigned responsibility for accomplishing specific tasks.

31. Significant Variances. Those differences between planned and actual performance requiring further review, analysis, or action. Thresholds should be established as to the magnitude of variances that will require variance analysis, and the thresholds should be revised as needed to provide meaningful analysis during execution of the contract.

32. Total Allocated Budget. The sum of all budgets allocated to the contract. Total allocated budget consists of the performance measurement baseline and all management reserve. The total allocated budget will reconcile directly to the contract budget base. Any differences will be documented as to quantity and cause.

33. Undistributed Budget. Budget applicable to contract effort that has not yet been identified to contract work breakdown structure elements at, or below, the lowest level of reporting to the Government.

34. Variances. (See definition 31, above.)

35. Work Breakdown Structure (WBS). (See Section 6-B.)

36. Work Package Budgets. Resources that are assigned formally by the contractor to accomplish a work package, expressed in dollars, hours, standards, or other definitive units.

37. Work Packages. Detailed tasks or material items identified by the contractor for accomplishing work required to complete the contract. A work package has the following characteristics:

a. It represents units of work at levels where work is performed.

b. It is clearly distinguishable from all other work packages.

c. It is assignable to a single organizational element.

d. It has scheduled start and completion dates and, as applicable, interim milestones; all of which are representative of physical accomplishment.

e. It has a budget or assigned value expressed in terms of dollars, manhours, or other measurable units.

f. Its duration is limited to a relatively short time span or it is subdivided by discrete value milestones to ease the objective measurement of work performed.

g. It is integrated with detailed engineering, manufacturing, or other schedules.

Budget at Completion (BAC): BAC is the amount planned to be spent in completing the entire contract.

Cost at Completion (CAC): CAC is the final cumulative dollar figure spent in completing the contract. This figure is obtained by taking the maximum (final) ACWP entry in each contract.

Percent Complete (PC): PC represents the portion of the entire contract that is complete to date. There are several ways to calculate PC. This thesis defines PC as the ratio of BCWP to TAB.

Appendix B: Interpolation Process and Script

This Appendix explains the procedure used to interpolate values for the six-month and three-month indexes. The overall process explanation is followed by a copy of the actual script used to interpolate the values, written in Paradox Application Language (PAL®).

Overall Process

Data definition and calculations were accomplished with personal computer database and spreadsheet software. The DAES database is a relational database which lends itself well to calculating and comparing subgroups of data to test the hypothesis. While it is not necessary to cover in great detail how the software works, it does help to have a basic understanding of database structure and functions in refining and calculating data.

A database is organized into rows or records (report dates, in this case) and columns or fields (the indexes, EACs and data elements defined in Appendix A). The basic data set never changes. There are numerous ways to manipulate the data, obtain subsets of the data, and categorize the data through use of database tools.

A query is perhaps the most useful anc most powerful of the database tools. A query is a request for a subset of the data, based on criteria established by the user. The result of a query is called the answer table. Some queries are calculations performed on existing fields while other queries are comparison operators, such as "less than," "greater than" or "equal to." The notable attribute of queries and answer tables is that the original data remains unaltered. Further queries can be performed on the new answer tables until the user gets the needed information. The spreadsheet software comes is most appropriate for statistical calculations. When

used in conjunction with the database software, it is a smooth process to export queried data between the database and the spreadsheet software for ease of calculation and graphing.

Interpolation

As mentioned in Chapter One, a shortcoming of the database was the lack of consistent reporting periods in the data. For eight of the twelve indexes selecte. .or evaluation, monthly data was necessary for calculating the indexes and their corresponding EACs. This monthly data was obtained by linear interpolation. While it is not known with certainty that the data increased linearly between submit dates, this assumption is necessary to obtain the most recent three months of data and the most recent six months of data. The interpolation process is based on the notion that the ratio of successive data points 's the same as the ratio of their corresponding submit dates.

Example: Given the following contract, calculate BCWP1 for 02/25/7(, where BCWP1 = the value for BCWP one month prior to 02/25/78.

SUBMIT DATE	BCWP
07/25/77	71
10/25/77	108
02/25/78	205
04/25/78	205
08/31/78	323

DATE1 = 02/25/78 - 30 days = 01/25/78

P = immediate predecessor in the contract to DATE1 = 10/25/77

S = immediate successor in the contract to DATE1 = 02/25/78.

	SUBMIT DATE	BCWP
P	10/25/77	108
DATE1	01/25/78	BCWP1
S	02/25/78	205

To interpolate the missing BCWP1 value, a set of ratios is set up and solved for BCWP1.

$$\frac{\text{DATE1} - \text{P}}{\text{S} - \text{P}} = \frac{\text{BCWP1} - 108}{205 - 108}$$

Solving this equation for BCWP1 provides the basic algorithm for interpolating missing values in the database.

$$\text{BCWP1} = \frac{(01/25/78 - 10/25/77) * (205-108)}{(02/25/78 - 10/25/77)} + 108 = 180.75$$

The same basic formula was used to calculate BCWP2, BCWP3, BCWP4 and BCWP5. Similar steps were taken to interpolate the five months previous data for each submit date in the database for ACWP and BCWS, which eventually allowed for the calculation of three and six month indexes and corresponding EACs.

The script in Paradox Application Language (PAL®) used to interpolate the values for one month prior, two months prior, three months prior, four months prior and five months prior to each report date of data is provided in the remaining pages.

```
;---------------------------------------------------------------
; CALCHIST
;---------------------------------------------------------------
; Script to interpolate BCWS, BCWP, and ACWP values from
;   historical data
;---------------------------------------------------------------

; Declare global constants
const
  DAYS_PER_MONTH    = 30
endConst

; Declare global variables
var
  SOURCE            Table
  WORKING_STATE     Logical
endVar

;---------------------------------------------------------------
; WORKING
;---------------------------------------------------------------
; This procedure lets the user know that something is
;   being done (i.e. the system has not locked up)
;---------------------------------------------------------------
proc WORKING( )
  if WORKING_STATE then
    message ( "Working, Hang On... /" )
  else
    message ( "Working, Hang On... \\" )
  endif
  WORKING_STATE = not WORKING_STATE  ; flip the value
endProc

;---------------------------------------------------------------
; INTERPOLATE_BCWS
;---------------------------------------------------------------
; This procedure determines what the BCWS was a number
;   of days ago (specified by DAYS_AGO)
; This is done using three cases:
;  - CASE   I: If no contract submit date exists before the
;              target BCWS date, the BCWS of the first
;              contract submit date is returned
;  - CASE  II: If a contract submit date matches the target
;              BCWS date exactly, the BCWS of that submit
;              date is returned.
;  - CASE III: If the target BCWS date falls between two
;              contract submit dates, the returned BCWS is
;              interpolated from the BCWS values of     those
;              two contract submit dates.
;---------------------------------------------------------------
proc INTERPOLATE_BCWS( DAYS_AGO Number,
                        CUR_PMO Number,
                        CUR_CNO Number,
                        CUR_SUBMITDATE Date ) Number
var
  TARGET_DATE         Date
  ANSWER              Number
  TC_SOURCE_INT       TCursor
  PREVIOUS_BCWS       Number
  PREVIOUS_SUBMITDATE Date
endVar

  TARGET_DATE = CUR_SUBMITDATE - DAYS_AGO
  TC_SOURCE_INT.open( SOURCE )
  TC_SOURCE_INT.home( )

  ; Locate the first report date in the current project/contract
  if not TC_SOURCE_INT.locate( "PMO", CUR_PMO, "CNO", CUR_CNO ) then
    msgStop( "Mara's Thesis Program",
      "ERROR - Locate in INTERPOLATE_BCWS failed" )
  endif

  if TC_SOURCE_INT.SUBMITDATE >= TARGET_DATE then
    ; CASE I: There is no previous report date
    return TC_SOURCE_INT.BCWS
  else

    ; Loop until a date after the target date
    PREVIOUS_BCWS = TC_SOURCE_INT.BCWS
    PREVIOUS_SUBMITDATE = TC_SOURCE_INT.SUBMITDATE
    if not TC_SOURCE_INT.locateNext( "PMO", CUR_PMO, "CNO", CUR_CNO ) then
      msgStop( "Mara's Thesis Program",
        "ERROR - locateNext in INTERPOLATE_BCWS failed" )
```

```
    endIf
    while TC_SOURCE_INT.SUBMITDATE < TARGET_DATE
      PREVIOUS_BCWS = TC_SOURCE_INT.BCWS
      PREVIOUS_SUBMITDATE = TC_SOURCE_INT.SUBMITDATE
      if not TC_SOURCE_INT.locateNext( "PMO", CUR_PMO, "CMO", CUR_CMO ) then
        msgStop( "Mara's Thesis Program",
          "ERROR - LocateNext in INTERPOLATE_BCWS failed" )
      endIf
    endWhile

    ; determine if interpolation is necessary
    if TC_SOURCE_INT.SUBMITDATE = TARGET_DATE then
      ; CASE II: Exact match of a submit date with the target date
      return TC_SOURCE_INT.BCWS
    else
      if TC_SOURCE_INT.SUBMITDATE > TARGET_DATE then
        ; CASE III: Need to interpolate a value
        ANSWER = ((Number(TARGET_DATE - PREVIOUS_SUBMITDATE) *
                  (TC_SOURCE_INT.BCWS - PREVIOUS_BCWS)) /
                 Number(TC_SOURCE_INT.SUBMITDATE - PREVIOUS_SUBMITDATE)) +
                PREVIOUS_BCWS
        return ANSWER
      else
        ; This should be impossible
        msgStop( "Mara's Thesis Program",
          "MAJOR FATAL ERROR - Impossible Condition in INTERPOLATE_BCWS" )
      endIf
    endIf
  endIf
endProc

;-------------------------------------------------------
; INTERPOLATE_BCWP
;-------------------------------------------------------
; This procedure determines what the BCWP was a number
;  of days ago (specified by DAYS_AGO)
; This is done using three cases:
; • CASE   I: If no contract submit date exists before the
;             target BCWP date, the BCWP of the first
;             contract submit date is returned
; • CASE  II: If a contract submit date matches the target
;             BCWP date exactly, the BCWP of that submit
;             date is returned.
; • CASE III: If the target BCWP date falls between two
;             contract submit dates, the returned BCWP is
;             interpolated from the BCWP values of the these
;             two contract submit dates.
;-------------------------------------------------------
proc INTERPOLATE_BCWP( DAYS_AGO Number,
                       CUR_PMO Number,
                       CUR_CMO Number,
                       CUR_SUBMITDATE Date ) Number
var
  TARGET_DATE         Date
  ANSWER              Number
  TC_SOURCE_INT       TCursor
  PREVIOUS_BCWP       Number
  PREVIOUS_SUBMITDATE Date
endVar

  TARGET_DATE = CUR_SUBMITDATE - DAYS_AGO
  TC_SOURCE_INT.open( SOURCE )
  TC_SOURCE_INT.home( )

  ; Locate the first report date in the current project/contract
  if not TC_SOURCE_INT.locate( "PMO", CUR_PMO, "CMO", CUR_CMO ) then
    msgStop( "Mara's Thesis Program",
      "ERROR - Locate in INTERPOLATE_BCWP failed" )
  endIf

  if TC_SOURCE_INT.SUBMITDATE >= TARGET_DATE then
    ; CASE I: There is no previous report date
    return TC_SOURCE_INT.BCWP
  else

    ; Loop until a date after the target date
    PREVIOUS_BCWP = TC_SOURCE_INT.BCWP
    PREVIOUS_SUBMITDATE = TC_SOURCE_INT.SUBMITDATE
    if not TC_SOURCE_INT.locateNext( "PMO", CUR_PMO, "CMO", CUR_CMO ) then
      msgStop( "Mara's Thesis Program",
        "ERROR - LocateNext in INTERPOLATE_BCWP failed" )
    endIf
    while TC_SOURCE_INT.SUBMITDATE < TARGET_DATE
```

```
      PREVIOUS_BCWP = TC_SOURCE_INT.BCWP
      PREVIOUS_SUBMITDATE = TC_SOURCE_INT.SUBMITDATE
      if not TC_SOURCE_INT.locateNext( "PNO", CUR_PNO, "CNO", CUR_CNO ) then
        msgStop( "Mara's Thesis Program",
          "ERROR - LocateNext in INTERPOLATE_BCWP failed" )
      endIf
    endWhile

    ; determine if interpolation is necessary
    if TC_SOURCE_INT.SUBMITDATE = TARGET_DATE then
      ; CASE II: Exact match of a submit date with the target date
      return TC_SOURCE_INT.BCWP
    else
      if TC_SOURCE_INT.SUBMITDATE > TARGET_DATE then
        ; CASE III: Need to interpolate a value
        ANSWER = ((Number(TARGET_DATE - PREVIOUS_SUBMITDATE) *
                  (TC_SOURCE_INT.BCWP - PREVIOUS_BCWP)) /
                 Number(TC_SOURCE_INT.SUBMITDATE - PREVIOUS_SUBMITDATE)) +
                PREVIOUS_BCWP
        return ANSWER
      else
        ; This should be impossible
        msgStop( "Mara's Thesis Program",
          "MAJOR FATAL ERROR - Impossible Condition in INTERPOLATE_BCWP" )
      endIf
    endIf
  endIf
endProc

;------------------------------------------------------------
;  INTERPOLATE_ACWP
;------------------------------------------------------------
; This procedure determines what the ACWP was a number
;  of days ago (specified by DAYS_AGO)
; This is done using three cases:
;  + CASE   I: If no contract submit date exists before the
;             target ACWP date, the ACWP of the first
;             contract submit date is returned
;  + CASE  II: If a contract submit date matches the target
;             ACWP date exactly, the ACWP of that submit
;             date is returned.
;  + CASE III: If the target ACWP date falls between two
;             contract submit dates, the returned ACWP is
;             interpolated from the ACWP values of the those
;             two contract submit dates.
;------------------------------------------------------------
proc INTERPOLATE_ACWP( DAYS_AGO Number,
                       CUR_PNO Number,
                       CUR_CNO Number,
                       CUR_SUBMITDATE Date ) Number
var
  TARGET_DATE      Date
  ANSWER           Number
  TC_SOURCE_INT    TCursor
  PREVIOUS_ACWP    Number
  PREVIOUS_SUBMITDATE Date
endVar

  TARGET_DATE = CUR_SUBMITDATE - DAYS_AGO
  TC_SOURCE_INT.open( SOURCE )
  TC_SOURCE_INT.home( )

  ; Locate the first report date in the current project/contract
  if not TC_SOURCE_INT.locate( "PNO", CUR_PNO, "CNO", CUR_CNO ) then
    msgStop( "Mara's Thesis Program",
      "ERROR - Locate in INTERPOLATE_ACWP failed" )
  endIf

  if TC_SOURCE_INT.SUBMITDATE >= TARGET_DATE then
    ; CASE I: There is no previous report date
    return TC_SOURCE_INT.ACWP
  else

    ; Loop until a date after the target date
    PREVIOUS_ACWP = TC_SOURCE_INT.ACWP
    PREVIOUS_SUBMITDATE = TC_SOURCE_INT.SUBMITDATE
    if not TC_SOURCE_INT.locateNext( "PNO", CUR_PNO, "CNO", CUR_CNO ) then
      msgStop( "Mara's Thesis Program",
        "ERROR - LocateNext in INTERPOLATE_ACWP failed" )
    endIf
    while TC_SOURCE_INT.SUBMITDATE < TARGET_DATE
      PREVIOUS_ACWP = TC_SOURCE_INT.ACWP
      PREVIOUS_SUBMITDATE = TC_SOURCE_INT.SUBMITDATE
```

```
      if not TC_SOURCE_INT.locateNext( "PNO", CUR_PNO, "CNO", CUR_CNO ) then
        msgStop( "Mara's Thesis Program",
          "ERROR - LocateNext in INTERPOLATE_ACWP failed" )
      endIf
    endWhile

    ; determine if interpolation is necessary
    if TC_SOURCE_INT.SUBMITDATE = TARGET_DATE then
      ; CASE II: Exact match of a submit date with the target date
      return TC_SOURCE_INT.ACWP
    else
      if TC_SOURCE_INT.SUBMITDATE > TARGET_DATE then
        ; CASE III: Need to interpolate a value
        ANSWER = ((Number(TARGET_DATE - PREVIOUS_SUBMITDATE) *
                   (TC_SOURCE_INT.ACWP - PREVIOUS_ACWP)) /
                  Number(TC_SOURCE_INT.SUBMITDATE - PREVIOUS_SUBMITDATE)) +
                 PREVIOUS_ACWP
        return ANSWER
      else
        ; This should be impossible
        msgStop( "Mara's Thesis Program",
          "MAJOR FATAL ERROR - Impossible Condition in INTERPOLATE_ACWP" )
      endIf
    endIf
  endIf
endProc

;------------------------------------------------------------
;  THE MAIN PROGRAM
;------------------------------------------------------------
;  The input comes from the table "source.db" in the :WORK:
;   directory, and the output is written to "result.db".
;  The "result.db" table is cleared if it exists.
;------------------------------------------------------------
method run(var eventInfo Event)
var
  TC_SOURCE        TCursor
  RESULT           Table
  TC_RESULT        TCursor
endVar

  ; Initialize global variables
  WORKING_STATE = TRUE

  ; Check that the SOURCE table exists then attach to it
  if not isTable( "source.db" ) then
    msgStop( "Mara's Thesis Program",
      "ERROR - I can't find the SOURCE.DB table" )
    return
  endIf
  SOURCE.attach( "source.db" )
  SOURCE.setIndex( "sind" )

  ; Delete the records from the RESULT table (if necessary)
  if isTable( "result.db" ) then
    RESULT.attach( "result.db" )
    TC_RESULT.open( RESULT )
    TC_RESULT.empty( )
    TC_RESULT.close( )
    msgInfo( "Mara's Thesis Program", "Clearing the RESULT table" )
  else
    RESULT = create "result.db"
             with "PNO"          : "N",
                  "CNO"          : "N",
                  "SUBMITDATE"   : "D",
                  "BCWS"         : "N",
                  "BCWS1"        : "N",
                  "BCWS2"        : "N",
                  "BCWS3"        : "N",
                  "BCWS4"        : "N",
                  "BCWS5"        : "N",
                  "BCWP"         : "N",
                  "BCWP1"        : "N",
                  "BCWP2"        : "N",
                  "BCWP3"        : "N",
                  "BCWP4"        : "N",
                  "BCWP5"        : "N",
                  "ACWP"         : "N",
                  "ACWP1"        : "N",
                  "ACWP2"        : "N",
                  "ACWP3"        : "N",
                  "ACWP4"        : "N",
                  "ACWP5"        : "N"
```

```
            endCreate
    endIf

    TC_SOURCE.open( SOURCE )
    TC_RESULT.open( RESULT )

    ; Scan the SOURCE table
    scan TC_SOURCE:

      ; Add a single record to the RESULT table
      TC_RESULT.edit( )
      TC_RESULT.insertAfterRecord( )
      TC_RESULT.PNO           = TC_SOURCE.PNO
      TC_RESULT.CNO           = TC_SOURCE.CNO
      TC_RESULT.SUBMITDATE    = TC_SOURCE.SUBMITDATE
      TC_RESULT.BCWS          = TC_SOURCE.BCWS
      TC_RESULT.BCWS1         = INTERPOLATE_BCWS( 1 * DAYS_PER_MONTH, TC_SOURCE.PNO,
                                  TC_SOURCE.CNO, TC_SOURCE.SUBMITDATE )
      TC_RESULT.BCWS2         = INTERPOLATE_BCWS( 2 * DAYS_PER_MONTH, TC_SOURCE.PNO,
                                  TC_SOURCE.CNO, TC_SOURCE.SUBMITDATE )
      TC_RESULT.BCWS3         = INTERPOLATE_BCWS( 3 * DAYS_PER_MONTH, TC_SOURCE.PNO,
                                  TC_SOURCE.CNO, TC_SOURCE.SUBMITDATE )
      TC_RESULT.BCWS4         = INTERPOLATE_BCWS( 4 * DAYS_PER_MONTH, TC_SOURCE.PNO,
                                  TC_SOURCE.CNO, TC_SOURCE.SUBMITDATE )
      TC_RESULT.BCWS5         = INTERPOLATE_BCWS( 5 * DAYS_PER_MONTH, TC_SOURCE.PNO,
                                  TC_SOURCE.CNO, TC_SOURCE.SUBMITDATE )
      TC_RESULT.BCWP          = TC_SOURCE.BCWP
      TC_RESULT.BCWP1         = INTERPOLATE_BCWP( 1 * DAYS_PER_MONTH, TC_SOURCE.PNO,
                                  TC_SOURCE.CNO, TC_SOURCE.SUBMITDATE )
      TC_RESULT.BCWP2         = INTERPOLATE_BCWP( 2 * DAYS_PER_MONTH, TC_SOURCE.PNO,
                                  TC_SOURCE.CNO, TC_SOURCE.SUBMITDATE )
      TC_RESULT.BCWP3         = INTERPOLATE_BCWP( 3 * DAYS_PER_MONTH, TC_SOURCE.PNO,
                                  TC_SOURCE.CNO, TC_SOURCE.SUBMITDATE )
      TC_RESULT.BCWP4         = INTERPOLATE_BCWP( 4 * DAYS_PER_MONTH, TC_SOURCE.PNO,
                                  TC_SOURCE.CNO, TC_SOURCE.SUBMITDATE )
      TC_RESULT.BCWP5         = INTERPOLATE_BCWP( 5 * DAYS_PER_MONTH, TC_SOURCE.PNO,
                                  TC_SOURCE.CNO, TC_SOURCE.SUBMITDATE )
      TC_RESULT.ACWP          = TC_SOURCE.ACWP
      TC_RESULT.ACWP1         = INTERPOLATE_ACWP( 1 * DAYS_PER_MONTH, TC_SOURCE.PNO,
                                  TC_SOURCE.CNO, TC_SOURCE.SUBMITDATE )
      TC_RESULT.ACWP2         = INTERPOLATE_ACWP( 2 * DAYS_PER_MONTH, TC_SOURCE.PNO,
                                  TC_SOURCE.CNO, TC_SOURCE.SUBMITDATE )
      TC_RESULT.ACWP3         = INTERPOLATE_ACWP( 3 * DAYS_PER_MONTH, TC_SOURCE.PNO,
                                  TC_SOURCE.CNO, TC_SOURCE.SUBMITDATE )
      TC_RESULT.ACWP4         = INTERPOLATE_ACWP( 4 * DAYS_PER_MONTH, TC_SOURCE.PNO,
                                  TC_SOURCE.CNO, TC_SOURCE.SUBMITDATE )
      TC_RESULT.ACWP5         = INTERPOLATE_ACWP( 5 * DAYS_PER_MONTH, TC_SOURCE.PNO,
                                  TC_SOURCE.CNO, TC_SOURCE.SUBMITDATE )
      TC_RESULT.endEdit( )

      WORKING( )   ; show the user that the computers not locked up!
    endScan

    TC_SOURCE.close( )
    TC_RESULT.close( )

    message( 'All Done...' )
    msgInfo( 'Mara's Thesis Program', 'Done Creating the RESULT Table...' )
endMethod
```

Appendix C: Descriptive Statistics

This appendix contains the descriptive statistics used to test the hypothesis. Each row is labeled in the far left column and the column entries are labeled below each column of values.

(All, Early, Middle or Late)

MEAN

SD

Coef of Variation

N=

n= %dev EAC1 %dev EAC2 . . . %dev EAC9 CAC TAB* BCWP ACWP

Each page contains one category of contracts. The All, Early, Middle and Late Stages are indicated in the upper left corner of the far left column.

The MEAN refers to the average percent deviation from Cost at Completion. It is calculated for each EAC.

$$\text{MEAN \% deviation from EAC} = \sum_{i=1}^{n} [((EAC-CAC)/CAC)*100]_i/n$$

The first row of values in the table are the average percent deviations from CAC for each of the nine EAC formulas, plus the average values of CAC, TAB, BCWP and ACWP.

The SD refers to the Standard Deviation. The SDs are the second row of values in the table.

The Coef of Variation refers to the Coefficient of Variation. This is the ratio of SD to MEAN, presented as a percentage. The third row of values are the coefficients of variation.

The N represents the number of contracts in the category while n represents the number of reports in the category. (Reports are subsets of contracts.)

*The TAB is replaced with BAC for the page with Management Reserve removed from the calculations.

N=321 contracts n=3803 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
all total													
MEAN	-2.45	-2.59	-2.52	-2.40	-2.37	-2.39	-1.01	-1.10	-1.05	318.22	292.32	215.95	228.68
SD	21.93	20.67	21.20	19.87	19.89	19.88	21.99	20.90	21.40	466.73	448.21	358.62	379.70
Coef of Variation	894.06	792.86	842.34	828.80	840.97	832.18	2188.42	1912.18	2050.13	147.28	152.84	166.08	165.90

N= 321 contracts n=302 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
all early													
MEAN	-7.11	-6.66	-7.76	-6.86	-7.07	-6.96	-1.83	-3.44	-2.54	325.78	289.51	73.36	78.38
SD	45.67	38.14	40.80	30.25	30.20	30.19	45.43	38.19	41.96	419.12	363.97	102.79	110.75
Coef of Variation	641.33	422.28	526.45	441.81	427.32	433.74	2483.67	1110.08	1651.62	128.66	131.34	140.12	141.30

N= 321contracts n=1073 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
all middle													
MEAN	-8.72	-8.78	-8.75	-7.99	-7.90	-7.95	-8.15	-8.10	-8.13	290.67	255.04	141.20	148.76
SD	23.18	23.36	23.23	23.95	24.00	23.98	24.02	24.34	24.16	411.83	372.28	213.17	228.68
Coef of Variation	265.77	268.03	265.60	299.80	303.92	301.68	300.63	300.07	303.95	141.68	145.97	150.97	152.38

N=321 contracts n=2428 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
all late													
MEAN	0.90	0.98	0.89	0.62	0.66	0.64	1.37	1.40	1.38	326.32	311.64	268.73	283.01
SD	16.07	16.06	16.06	16.05	16.07	16.06	16.15	16.15	16.15	492.64	483.84	415.34	439.37
Coef of Variation	1881.50	1710.47	1806.30	2443.09	2271.07	2384.07	1104.82	1079.04	1094.33	150.97	155.28	155.72	155.25

ALL CONTRACTS

no mr all N=239 contracts n=3608 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	BAC	BCWP	ACWP
MEAN	-5.60	-5.64	-5.56	-5.40	-5.36	-5.38	-4.16	-4.26	-4.20	395.17	298.81	261.78	332.33
SD	21.80	20.57	21.13	20.14	20.18	20.15	21.87	21.02	21.45	43.64	58.58	60.73	51.06
Coef of Variation	398.25	364.71	379.88	373.11	376.24	374.88	526.45	493.79	510.64	11.04	19.76	23.20	15.36

no mr early N=239 contracts n=270 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	BAC	BCWP	ACWP
MEAN	-10.94	-12.22	-11.51	-10.23	-10.47	-10.35	-5.87	-7.31	-6.49	453.39	302.60	76.72	96.60
SD	42.80	33.82	38.25	30.16	30.15	30.11	42.58	36.04	39.47	419.07	243.11	58.06	80.39
Coef of Variation	391.20	276.77	332.42	294.80	288.10	290.93	724.80	492.87	607.80	92.43	80.37	75.67	83.31

no mr middle N=239 contracts n=990 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	BAC	BCWP	ACWP
MEAN	-11.42	-11.51	-11.46	-10.72	-10.64	-10.69	-8.93	-8.93	-8.93	248.22	214.17	140.44	158.44
SD	23.22	23.31	23.24	23.92	24.01	23.97	24.05	24.31	24.18	152.95	90.60	64.42	70.43
Coef of Variation	203.37	202.51	202.76	223.09	225.64	224.29	269.19	272.19	270.44	61.62	42.26	45.87	44.45

no mr late N=239 contracts n=2239 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	BAC	BCWP	ACWP
MEAN	-2.21	-2.22	-2.22	-2.44	-2.39	-2.41	-1.83	-1.81	-1.82	368.11	282.83	253.72	319.33
SD	15.77	15.78	15.77	15.67	15.68	15.67	15.90	15.91	15.91	97.10	77.21	73.44	81.08
Coef of Variation	714.58	708.80	711.69	641.84	655.14	649.60	870.59	879.20	873.55	26.52	27.30	28.95	25.38

ALL: MANAGEMENT RESERVE REMOVED

pre-prod all													
MEAN	-5.27	-5.40	-5.37	-5.40	-5.40	-5.45	-3.88	-3.98	-3.82	385.27	347.04	281.23	278.95
SD	28.44	24.01	25.12	23.34	23.39	23.38	25.91	24.17	25.03	595.77	569.50	481.88	490.05
Coef of Variation	502.19	437.45	467.83	425.92	433.17	428.89	672.01	608.83	639.99	154.64	164.11	178.73	175.95
N=112 contracts n=1454 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP

pre-prod early													
MEAN	-6.41	-9.11	-7.67	-7.61	-7.18	-7.35	-0.89	-2.91	-1.72	431.94	331.08	91.04	100.87
SD	61.19	43.89	52.36	37.42	37.81	37.62	56.70	43.99	50.61	561.15	442.72	134.31	147.19
Coef of Variation	954.27	481.81	682.51	491.83	526.85	511.59	6367.60	1512.43	2943.43	129.91	133.72	147.53	145.92
N=112 contracts n=100 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP

pre-prod middle													
MEAN	-12.51	-12.68	-12.50	-12.04	-11.97	-12.03	-9.77	-9.88	-9.85	318.31	264.32	146.22	164.92
SD	25.88	25.89	25.87	26.63	26.65	26.62	26.79	26.81	26.76	498.56	446.54	256.10	272.82
Coef of Variation	208.83	204.21	206.53	221.24	222.61	221.23	274.27	271.28	271.89	157.40	168.94	175.68	176.10
N=112 contracts n=408 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP

pre-prod late													
MEAN	-2.04	-2.03	-2.04	-2.45	-2.40	-2.43	-1.64	-1.57	-1.61	410.31	384.15	328.87	347.78
SD	19.03	19.01	19.02	18.93	18.94	18.93	19.14	19.13	19.14	635.03	622.52	532.84	565.42
Coef of Variation	931.83	938.65	933.52	773.04	789.23	780.30	1169.34	1218.14	1190.12	154.77	162.05	162.02	162.58
N=112 contracts n=946 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP

PRE-PRODUCTION CONTRACTS

prod all	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	-0.29	-0.30	-0.29	-0.00	0.00	0.00	1.15	1.16	1.18	304.10	283.88	206.14	221.46
SD	16.93	16.99	16.96	16.91	16.96	16.93	17.89	18.07	17.98	318.05	294.35	226.18	250.49
Coef of Variation	6083.49	5576.28	5907.97	506557.52	411574.36	776807.16	1554.84	1575.43	1556.48	104.59	103.69	109.72	113.11
N=136 contracts													
n=1398 reports													

prod early	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	-7.72	-7.80	-7.74	-6.48	-3.10	-6.03	-2.28	-3.02	-2.68	362.20	309.37	82.42	85.99
SD	27.32	27.27	27.29	25.80	25.51	25.60	33.26	32.78	32.98	336.93	326.09	82.53	86.00
Coef of Variation	353.97	349.62	352.73	472.59	418.60	430.38	1459.08	1085.86	1232.69	95.88	105.08	100.14	100.01
N=136 contracts													
n=113 reports													

prod middle	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	-4.84	-4.77	-4.80	-3.93	-3.81	-3.84	-2.41	-2.16	-2.25	321.87	293.80	164.81	173.31
SD	21.75	21.99	21.84	22.62	22.75	22.72	22.81	23.53	23.21	325.66	289.36	170.54	185.37
Coef of Variation	449.86	460.72	454.80	575.62	597.66	591.44	948.13	1093.76	1033.46	101.14	98.56	103.48	106.96
N=321 contracts													
n=354 reports													

prod late	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	2.36	2.30	2.33	2.15	2.19	2.17	2.92	2.91	2.91	291.60	277.09	236.88	256.21
SD	11.82	11.81	11.81	11.87	11.92	11.89	11.88	11.90	11.87	312.24	292.37	248.06	275.88
Coef of Variation	501.16	512.49	506.02	551.82	543.36	547.77	406.19	409.21	407.31	107.11	105.51	104.72	107.60
N=136 contracts													
n=931 reports													

PRODUCTION CONTRACTS

cp all N=137 contracts n=1830 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	-3.88	-4.03	-3.96	-3.98	-3.91	-3.94	-2.66	-2.77	-2.71	297.33	276.67	207.56	218.55
SD	22.37	21.67	22.03	20.72	20.71	20.71	22.34	21.62	21.98	614.02	498.65	402.30	427.32
Coef of Variation	676.80	537.36	558.03	523.04	529.32	526.50	840.21	780.03	810.21	172.88	180.80	193.84	195.52

cp early N=137 contracts n=90 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	-3.88	-4.03	-3.96	-3.98	-3.91	-3.94	-2.66	-2.77	-2.71	297.33	276.67	207.56	218.56
SD	22.37	21.67	22.03	20.72	20.71	20.71	22.34	21.62	21.98	514.02	498.65	402.30	427.32
Coef of Variation	676.80	537.36	558.03	523.04	529.32	526.50	840.21	780.03	810.21	172.88	180.80	193.84	196.52

cp middle N=137contracts n=466 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	-11.52	-11.64	-11.58	-11.18	-11.11	-11.16	-9.19	-9.26	-9.24	247.29	213.24	119.73	125.86
SD	24.10	24.22	24.12	24.31	24.29	24.30	24.74	24.79	24.71	391.28	365.36	214.08	225.57
Coef of Variation	209.16	208.12	208.29	217.36	218.72	217.73	269.14	268.00	267.46	158.23	171.34	178.80	179.23

cp late N=137 contracts n=1074 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	-0.29	-0.30	-0.30	-0.54	-0.49	-0.52	0.08	0.11	0.09	318.82	302.42	268.30	272.31
SD	15.70	15.68	15.69	15.63	15.65	15.64	15.78	15.78	15.77	560.71	549.57	467.60	497.15
Coef of Variation	5409.56	5156.10	5264.66	2914.64	3178.36	3021.03	18682.25	13823.23	16668.18	178.98	181.72	180.96	182.57

COST PLUS CONTRACTS

# all N=13 contracts n=98 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	2.98	2.88	2.92	3.80	3.56	3.58	3.47	3.32	3.37	214.81	219.60	169.28	170.41
SD	6.83	6.59	6.68	6.46	6.33	6.37	7.41	6.98	7.11	128.89	127.26	113.36	114.63
Coef of Variation	229.08	228.54	228.10	170.18	178.05	178.24	213.42	210.41	210.63	59.12	57.95	66.98	67.27

# early N=13 contracts n= 5 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	4.82	4.43	4.66	5.82	5.01	5.39	4.81	3.79	4.41	288.20	304.40	80.60	82.20
SD	6.66	6.32	6.51	3.08	2.76	2.89	5.44	4.23	4.94	137.27	143.72	43.79	46.63
Coef of Variation	138.11	142.86	139.83	54.51	54.91	53.71	112.93	111.77	112.10	47.63	47.21	54.20	56.73

# middle N=13 contracts n=26 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	2.96	2.88	2.75	4.88	4.58	4.60	4.45	4.02	4.15	191.68	198.98	112.88	114.80
SD	8.52	8.09	8.19	8.34	8.07	8.14	10.28	9.39	9.58	125.62	128.99	81.06	87.42
Coef of Variation	292.08	303.78	297.18	170.22	176.36	177.06	230.86	233.44	231.17	65.49	65.49	71.81	76.15

# late N=13 contracts n=68 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	2.86	2.85	2.86	3.04	3.08	3.05	3.00	3.02	3.00	217.73	221.78	197.36	198.16
SD	6.15	6.05	6.10	5.79	5.77	5.78	6.22	6.11	6.16	128.20	124.49	116.65	118.98
Coef of Variation	215.34	212.45	214.02	190.43	188.50	189.53	207.37	202.49	206.11	57.98	56.14	59.11	60.03

FIRM FIXED CONTRACTS

lp all

	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	-1.64	-1.78	-1.70	-1.62	-1.49	-1.51	0.03	-0.04	0.00	337.40	310.18	225.69	240.77
SD	22.00	20.04	20.92	19.62	19.67	19.54	22.12	20.86	21.47	433.98	410.24	328.47	346.36
Coef of Variation	1336.27	1126.97	1227.79	1204.54	1317.77	1297.63	64812.17	51068.20	784618.40	128.63	132.28	145.54	143.86

N=169 contracts
n=2053 reports

lp early

	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	-7.60	-8.88	-8.19	-7.07	-7.38	-7.24	-2.07	-3.56	-2.76	329.40	263.58	73.19	79.49
SD	44.23	32.24	38.06	27.33	27.31	27.26	44.37	36.10	40.34	389.14	307.13	94.20	103.53
Coef of Variation	582.17	362.91	464.50	386.28	370.02	376.40	2141.33	1014.62	1462.50	118.14	116.52	128.70	130.24

N=169 contracts
n=195reports

lp middle

	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	-7.10	-7.09	-7.09	-6.08	-5.97	-6.03	-4.27	-4.12	-4.19	331.31	292.34	160.31	169.30
SD	22.59	22.82	22.67	23.79	23.89	23.85	23.56	24.15	23.87	432.65	382.23	215.40	230.59
Coef of Variation	318.29	321.57	319.82	390.96	399.91	395.49	551.87	586.66	569.69	130.59	130.75	134.36	136.20

N=169 contracts
n=578 reports

lp late

	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	1.72	1.71	1.72	1.39	1.44	1.41	2.30	2.34	2.32	341.36	325.33	278.45	297.61
SD	14.82	14.80	14.81	14.84	14.86	14.86	14.88	14.89	14.88	441.25	434.84	377.57	396.67
Coef of Variation	859.40	867.96	863.55	1068.99	1032.06	1061.86	646.86	637.12	642.58	129.26	133.66	135.60	133.29

N=169 contracts
n=1280 reports

FIXED PRICE CONTRACTS

Army all N=48 contracts n=606 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	-10.00	-10.71	-10.33	-10.70	-10.68	-10.59	-8.27	-8.88	-8.55	213.72	172.97	131.94	130.81
SD	36.88	30.13	32.01	26.38	26.40	26.38	34.76	30.26	32.58	275.68	236.22	106.44	202.64
Coef of Variation	358.76	281.28	318.73	246.53	247.53	248.89	420.16	340.70	381.08	128.90	136.57	148.12	144.95

Army early N=48 contracts n=41 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	-1.64	-11.58	-8.04	-15.34	-16.59	-16.47	3.70	-6.63	-0.29	179.16	115.61	30.06	38.27
SD	100.62	68.11	84.03	33.71	33.88	33.78	91.91	84.13	79.36	244.04	133.98	36.82	56.16
Coef of Variation	6535.68	670.76	1390.94	219.71	217.38	218.16	2484.94	1150.60	27116.90	136.56	115.90	122.53	146.74

Army middle N=48 contracts n=171 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	-18.14	-18.29	-18.21	-17.12	-17.09	-17.10	-14.38	-14.49	-14.42	192.75	144.19	81.40	86.87
SD	27.17	27.42	27.21	27.73	27.66	27.70	29.22	29.32	29.17	242.48	191.37	116.88	120.52
Coef of Variation	149.76	149.94	149.40	161.94	161.87	161.96	203.62	202.41	202.31	125.80	132.72	143.58	138.74

Army late N=48 contracts n=394 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	-7.36	-7.33	-7.36	-7.43	-7.36	-7.40	-6.88	-6.80	-6.85	226.74	191.43	164.48	173.35
SD	24.31	24.31	24.30	24.33	24.36	24.34	24.46	24.49	24.46	291.54	259.20	222.48	230.63
Coef of Variation	330.79	331.49	330.70	327.50	330.82	328.82	355.54	360.26	356.91	128.56	136.40	135.26	133.05

ARMY CONTRACTS

Navy all													
MEAN	0.90	0.99	0.99	0.61	0.65	0.62	2.02	2.07	2.04	348.31	330.93	244.33	261.12
SD	14.82	14.92	14.86	14.84	14.70	14.81	15.41	15.47	15.41	601.30	581.75	463.80	405.65
Coef of Variation	1504.30	1508.80	1501.50	2443.88	2268.84	2371.74	762.71	748.33	754.81	173.63	175.79	189.62	189.62
N=144 contracts													
n=1424 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP

Navy early													
MEAN	-5.88	-5.90	-5.91	-6.28	-6.31	-6.28	-2.62	-2.75	-2.71	382.41	344.50	97.38	103.62
SD	24.80	24.77	24.76	21.33	20.74	21.00	28.72	28.10	28.32	574.37	505.14	149.80	160.78
Coef of Variation	421.02	419.88	419.24	340.74	328.58	334.34	1094.18	1022.73	1046.83	150.20	146.50	153.83	155.17
N=144contracts													
n=112 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP

Navy middle													
MEAN	-3.42	-3.33	-3.37	-3.63	-3.45	-3.49	-1.48	-1.28	-1.38	340.07	312.84	172.94	182.76
SD	19.13	19.49	19.28	20.30	20.30	20.30	19.77	20.22	19.95	543.54	495.87	284.83	304.71
Coef of Variation	558.54	586.08	572.62	575.76	588.28	580.95	1335.85	1585.43	1440.28	159.83	158.54	164.70	166.73
N=144 contracts													
n=411 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP

Navy late													
MEAN	3.57	3.53	3.55	3.07	3.11	3.09	3.98	3.98	3.98	344.83	338.91	290.09	310.93
SD	9.81	9.79	9.80	9.88	9.90	9.89	9.92	9.92	9.92	626.70	621.43	534.09	570.47
Coef of Variation	275.27	277.20	276.15	321.58	318.73	320.23	249.57	249.35	249.48	181.74	184.45	184.11	183.48
N=144 contracts													
n=1001 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP

NAVY CONTRACTS

	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
USAF all													
MEAN	-2.12	-2.19	-2.15	-1.38	-1.34	-1.36	-0.38	-0.42	-0.40	330.99	305.70	224.40	235.81
SD	18.69	18.86	18.87	19.26	19.33	19.20	19.48	19.53	19.51	365.04	344.74	283.43	293.92
Coef of Variation	889.60	860.19	875.88	1396.68	1442.79	1413.41	5098.18	4689.47	4863.15	110.29	112.77	126.31	124.64
N=127contracts													
n=1638 reports													
USAF early													
MEAN	-9.19	-9.37	-9.26	-4.60	-4.93	-4.77	-2.38	[illegible]	-2.68	326.00	256.96	67.63	70.88
SD	31.67	31.61	31.60	34.3[illegible]	34.46	34.36	35.70	36.34	35.63	292.06	218.06	57.41	60.94
Coef of Variation	344.60	336.40	341.60	746.39	698.31	720.03	1500.91	1171.64	1336.28	89.58	84.86	84.89	85.98
N=127 contracts													
n=148 reports													
USAF middle													
MEAN	-7.91	-7.84	-6.29	-6.17	-6.24	-5.03	-5.03	-5.05	-6.66	324.11	317.50	183.28	187.83
SD	21.31	21.33	22.03	22.16	22.10	22.13	22.41	22.29	21.81	177.08	156.73	91.66	97.48
Coef of Variation	269.33	271.87	349.97	359.24	354.03	440.13	445.71	441.78	327.25	54.64	49.36	50.01	51.90
N=127 contracts													
n=471 reports													
USAF late													
MEAN	1.61	1.49	1.51	1.38	1.41	1.39	2.08	2.09	2.07	349.90	338.42	285.96	300.81
SD	13.53	13.50	13.52	13.47	13.60	13.48	13.55	13.55	13.55	393.04	381.14	326.33	337.21
Coef of Variation	894.51	903.40	897.77	989.56	964.27	973.30	650.10	647.41	653.38	112.33	113.29	114.12	112.10
N=127 contracts													
n=1019 reports													

USAF CONTRACTS

airframe all													
MEAN	-0.81	-0.69	-0.64	-1.00	-0.99	-1.00	0.36	0.27	0.32	701.52	752.52	561.61	560.10
SD	12.66	12.60	12.57	12.32	12.36	12.34	12.29	12.32	12.31	731.52	683.91	566.93	562.77
Coef of Variation	2064.33	1822.71	1961.43	1232.77	1244.57	1237.07	3439.13	4618.01	3894.49	92.43	90.88	100.95	100.46
N=22contracts n=228 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP

airframe early													
MEAN	-14.08	-14.69	-14.34	-14.72	-16.01	-14.86	-10.73	-11.69	-11.14	756.56	633.94	189.56	205.67
SD	22.82	22.90	22.80	22.39	22.18	22.31	22.44	22.37	22.42	743.46	608.58	197.68	218.47
Coef of Variation	162.04	156.52	159.64	152.12	147.78	150.29	209.16	191.34	201.18	98.27	96.00	104.29	108.23
N=22 contracts n=18 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP

airframe middle													
MEAN	-1.39	-1.53	-1.42	-1.86	-1.82	-1.83	0.56	0.39	0.62	754.82	688.02	368.98	385.16
SD	8.18	8.15	8.17	7.84	7.95	7.89	8.54	8.42	8.51	676.73	584.90	314.85	339.28
Coef of Variation	591.83	532.37	574.54	424.70	437.67	431.99	1566.13	2146.93	1650.44	89.65	85.01	85.33	88.09
N=22 contracts n=55 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP

airframe late													
MEAN	1.23	1.22	0.89	0.93	0.91	1.58	1.61	1.58	0.95	1120.22	1133.06	1001.58	1008.17
SD	11.20	11.23	11.00	11.02	11.01	11.20	11.18	11.21	11.03	1048.50	1059.33	943.87	951.49
Coef of Variation	908.74	919.43	1229.96	1187.98	1218.40	709.78	694.02	711.01	1163.94	93.60	93.49	94.24	94.38
N=22 contracts n=155 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP

AIRFRAME CONTRACTS

electronics all N=43 contracts n=640 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	-2.61	-2.67	-2.53	-2.02	-2.09	-2.07	-1.22	-1.38	-1.30	228.98	211.88	154.07	158.71
SD	16.62	16.47	16.60	16.76	16.87	16.70	16.68	16.54	16.59	234.41	217.14	178.04	183.18
Coef of Variation	667.84	640.07	651.51	831.45	799.04	808.06	1361.78	1218.47	1277.26	103.27	102.58	114.26	115.42

electronics early N=43 contracts n=43 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	-14.84	-14.81	-14.58	-10.58	-11.37	-11.00	-11.17	-11.89	-11.51	247.91	208.58	58.40	57.81
SD	18.54	18.50	18.52	21.45	20.27	20.71	21.49	20.32	20.76	214.27	172.57	52.96	52.42
Coef of Variation	128.98	128.58	127.07	202.71	178.27	188.26	192.41	170.86	180.33	86.43	83.64	90.68	90.67

electronics middle N=43 contracts n=160 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	-8.74	-8.86	-8.78	-8.02	-8.18	-8.13	-6.40	-6.67	-6.59	225.28	193.19	107.74	110.39
SD	19.32	19.24	19.28	20.28	20.17	20.21	19.79	19.54	19.63	225.53	192.52	116.46	118.32
Coef of Variation	221.06	217.30	219.52	252.89	247.13	248.47	309.04	292.87	298.64	100.12	99.81	108.09	107.18

electronics late N=43 contracts n=337 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	1.99	1.94	1.97	1.93	1.98	1.96	2.50	2.51	2.51	226.13	221.07	188.28	194.53
SD	12.67	12.64	12.66	12.50	12.53	12.51	12.81	12.80	12.81	241.40	232.48	198.94	207.75
Coef of Variation	636.82	649.96	641.49	648.21	632.30	640.45	511.91	510.62	510.66	107.23	105.18	105.66	106.80

ELECTRONICS CONTRACTS

engine all	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	2.48	2.27	2.38	2.63	2.60	2.65	3.07	2.92	2.99	182.81	183.77	147.63	149.30
SD	14.60	14.42	14.44	14.81	14.86	14.83	14.87	14.80	14.79	175.18	177.14	155.94	155.07
Coef of Variation	584.36	634.21	606.74	564.05	553.19	558.82	483.69	507.53	494.30	95.81	96.39	105.63	103.86
N=12 contracts n=117 reports													

engines early	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	-0.36	0.12	-0.18	2.61	2.32	2.45	3.10	3.38	3.20	120.40	128.80	32.80	32.80
SD	27.87	28.06	27.93	27.60	27.58	27.58	27.86	27.87	27.86	53.72	73.82	17.48	16.84
Coef of Variation	7812.86	24162.77	15314.20	1097.40	1186.38	1128.05	897.34	830.16	871.33	44.62	57.31	53.31	51.36
N=12 contracts n= 5 report dates													

engines middle	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	-2.82	-3.69	-3.20	-1.98	-1.78	-1.80	-1.76	-2.36	-2.08	99.84	100.10	55.64	58.23
SD	19.04	18.59	18.76	20.76	20.91	20.79	20.14	19.83	19.86	78.38	89.05	55.27	62.68
Coef of Variation	674.18	517.17	586.77	1048.50	1176.86	1097.78	1149.10	842.82	963.00	78.51	88.97	98.99	107.59
N=12 contracts n=31 reports													

engines late	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	4.69	4.65	4.67	4.39	4.42	4.41	4.92	4.91	4.91	218.42	219.19	189.85	191.35
SD	10.68	10.63	10.66	10.36	10.37	10.38	10.82	10.80	10.82	194.53	195.15	167.94	165.92
Coef of Variation	227.63	228.58	228.16	236.60	234.73	235.24	219.94	220.08	220.19	89.08	89.03	88.46	86.71
N=12 contracts n=81 reports													

ENGINE CONTRACTS

equipment all N=18 contracts n=213 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	1.67	1.58	1.61	3.04	3.10	3.08	3.46	3.43	3.42	205.47	165.40	131.97	135.08
SD	23.77	23.58	23.67	23.02	23.88	23.90	23.64	23.38	23.51	258.75	230.34	170.11	180.08
Coef of Variation	1425.20	1495.59	1467.30	787.86	769.81	781.64	683.81	682.22	687.65	125.93	117.86	128.90	133.30

equipment early N=18 contracts n=22 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	22.38	22.02	22.11	30.16	30.11	30.18	30.44	30.04	30.19	227.23	221.09	57.32	56.46
SD	44.66	43.88	44.29	41.18	41.27	41.19	39.08	38.30	38.66	257.09	193.98	57.21	56.34
Coef of Variation	199.78	199.17	200.34	136.52	137.06	136.47	128.39	127.49	128.12	113.14	87.74	99.81	99.80

equipment middle N=18 contracts n=55 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	-6.62	-6.66	-6.60	-4.27	-3.99	-4.21	-4.00	-3.86	-4.03	286.84	246.95	134.24	136.86
SD	27.33	27.32	27.31	27.80	27.60	27.72	27.98	27.84	27.90	308.56	245.97	139.73	148.06
Coef of Variation	410.21	410.32	413.62	651.03	690.99	658.84	698.59	721.52	692.43	107.66	99.61	104.10	108.34

equipment late N=18 contracts n=136 records	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	1.63	1.60	1.62	1.60	1.60	1.61	2.11	2.07	2.10	169.13	170.40	143.13	147.16
SD	13.47	13.38	13.43	13.40	13.51	13.60	13.64	13.46	13.51	229.52	226.82	189.98	201.24
Coef of Variation	826.38	838.89	828.70	841.59	841.92	838.97	642.20	651.13	643.39	135.70	133.11	132.72	136.76

EQUIPMENT CONTRACTS

ground all													
MEAN	-2.17	-2.21	-2.18	-1.98	-1.98	-1.97	-1.00	-1.05	-1.02	82.21	74.31	53.78	58.89
SD	8.38	8.39	8.37	8.12	8.02	8.03	8.80	8.87	8.82	89.30	69.51	48.80	64.01
Coef of Variation	384.45	378.67	383.88	415.06	404.77	406.78	876.64	841.78	865.01	108.63	93.54	90.72	109.08
N=8 contracts n=88 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP

ground early													
MEAN	-9.83	-10.04	-9.91	-6.67	-6.32	-6.52	-0.90	-0.86	-0.86	163.57	124.00	36.86	43.14
SD	13.60	13.12	13.38	10.28	10.84	10.52	16.41	15.87	16.20	135.28	92.88	30.93	40.70
Coef of Variation	138.24	130.68	134.90	163.76	171.56	161.41	1829.58	1860.89	1895.59	82.69	74.91	83.91	94.34
N=8 contracts n=7 records	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP

ground middle													
MEAN	-1.87	-2.01	-1.90	-1.88	-1.94	-1.81	-0.81	-0.93	-0.73	94.75	89.65	48.20	52.76
SD	10.96	11.39	11.16	11.93	11.47	11.59	12.16	12.79	12.41	94.41	80.34	44.69	57.06
Coef of Variation	584.06	565.17	589.06	719.98	590.39	640.93	1978.75	1369.48	1703.02	99.64	89.61	92.72	108.16
N=8 contracts n=20 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP

ground late													
MEAN	-1.37	-1.36	-1.38	-1.50	-1.48	-1.49	-1.15	-1.12	-1.14	68.31	63.22	57.89	62.54
SD	6.02	5.88	5.95	6.01	6.04	6.02	6.09	5.98	6.03	76.32	59.75	51.73	68.63
Coef of Variation	440.31	434.59	437.22	401.30	408.09	403.90	530.65	534.65	530.78	111.73	94.51	89.68	109.73
N=8 contracts n=59 records	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP

GROUND CONTRACTS

missiles all N=43 contracts n=516 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	-2.17	-2.20	-2.18	-2.16	-2.14	-2.16	-0.69	-0.68	-0.66	476.28	446.08	326.86	345.97
SD	20.26	20.33	20.29	20.26	20.21	20.23	20.77	20.84	20.80	762.59	746.10	599.12	644.39
Coef of Variation	932.63	923.99	929.98	937.32	944.43	940.16	3030.98	3049.94	3048.94	160.12	167.26	183.28	186.28

missiles early N=43 contracts n=40 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	-6.65	-6.44	-6.55	-3.99	-4.52	-4.26	-0.13	-0.41	-0.28	567.49	504.88	130.93	136.60
SD	32.64	32.61	32.68	31.67	31.21	31.46	36.68	36.42	36.65	666.50	606.94	168.60	178.04
Coef of Variation	678.23	509.90	589.20	794.26	690.34	739.33	27084.83	8678.27	12795.34	117.46	120.02	128.78	130.33

missiles middle N=43 contracts n=152 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	-6.60	-6.65	-6.62	-6.13	-5.99	-6.06	-4.15	-4.03	-4.09	386.72	364.20	196.68	205.27
SD	24.68	24.68	24.76	25.33	25.38	25.34	25.36	25.66	25.47	611.31	577.20	339.53	358.56
Coef of Variation	373.64	374.23	374.07	412.90	423.61	417.93	610.68	636.54	622.74	158.48	162.96	172.65	174.68

missiles late N=43 contracts n=323 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	0.34	0.29	0.32	-0.06	-0.04	-0.06	0.88	0.86	0.87	507.57	482.04	412.43	436.11
SD	14.94	14.96	14.94	14.84	14.85	14.85	14.98	15.00	14.98	832.68	825.94	703.81	756.56
Coef of Variation	4340.34	5077.11	4623.79	22850.16	41369.99	26811.83	1704.95	1748.43	1720.32	164.06	171.34	170.65	173.14

MISSILE CONTRACTS

ships all N=19 contracts n=244 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	1.17	1.15	1.16	0.62	0.47	0.50	1.33	1.28	1.30	809.75	567.00	419.60	449.38
SD	11.86	12.03	11.94	14.20	14.17	14.18	12.89	13.00	12.92	719.41	692.23	572.21	594.39
Coef of Variation	1011.86	1044.46	1029.61	2738.36	3038.29	2846.09	967.51	1033.14	995.54	117.96	122.09	136.37	132.56

ships early N=19 contracts n=24 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	-10.69	-10.65	-10.71	-17.28	-17.40	-17.37	-15.52	-15.62	-15.65	360.33	298.00	87.21	91.46
SD	19.48	19.79	19.58	22.83	22.50	22.60	23.39	23.31	23.23	441.41	365.26	119.65	123.81
Coef of Variation	182.29	185.79	182.78	132.28	129.32	130.18	150.74	149.23	148.40	122.50	122.57	137.20	136.38

ships middle N=19 contracts n=77 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	-1.70	-1.73	-1.71	-1.03	-1.21	-1.09	-0.09	-0.30	-0.16	606.06	544.30	297.13	311.36
SD	13.22	13.56	13.36	16.64	15.67	15.64	12.91	13.27	13.06	688.48	609.83	342.49	360.24
Coef of Variation	776.48	785.53	780.31	1619.17	1297.96	1440.26	14381.94	4438.71	8281.83	113.79	112.04	115.27	115.70

ships late N=19 contracts n=143 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	4.71	4.68	4.70	4.34	4.37	4.35	4.93	4.93	4.93	664.15	624.38	541.33	582.07
SD	6.75	6.74	6.75	7.77	7.72	7.74	6.68	6.63	6.66	788.75	763.89	673.41	694.93
Coef of Variation	143.18	143.98	143.68	179.15	176.74	178.04	136.62	134.42	136.07	117.21	122.34	124.40	119.39

SHIP CONTRACTS

space all	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	-10.30	-11.01	-10.64	-10.28	-10.18	-10.24	-7.85	-8.38	-8.11	287.08	218.80	156.86	178.42
SD	38.12	30.30	34.02	28.33	28.52	28.40	36.40	30.83	33.67	284.87	213.94	172.60	208.01
Coef of Variation	370.23	275.25	319.80	278.24	279.98	277.42	463.46	367.57	415.23	99.23	97.78	110.03	116.77
N=25 contracts n=330 reports													

space early	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	-7.48	-15.67	-11.31	-13.81	-14.26	-14.09	2.81	-4.77	-0.60	464.81	261.86	65.84	85.61
SD	94.25	53.55	74.87	35.40	36.71	35.95	63.86	54.10	70.31	408.37	215.19	53.48	79.55
Coef of Variation	1260.82	341.77	660.09	257.08	257.58	255.10	2065.37	1134.73	11068.74	89.39	82.24	81.23	92.92
N=25 contracts n=31 reports													

space middle	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	-16.32	-16.27	-16.32	-13.86	-13.68	-13.80	-12.28	-12.03	-12.22	248.42	177.00	97.77	113.64
SD	26.77	26.63	26.71	28.70	28.74	28.72	28.63	28.56	28.59	277.64	170.38	100.22	144.02
Coef of Variation	164.07	163.67	163.61	206.98	210.02	208.16	233.06	237.39	233.92	111.72	96.25	102.50	126.74
N=26 contracts n=95 reports													

space late	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	-8.02	-7.98	-8.00	-8.13	-8.03	-8.09	-7.43	-7.29	-7.37	279.94	231.20	196.49	217.84
SD	26.81	26.80	26.81	26.91	26.98	26.93	26.98	27.03	27.00	258.92	228.80	195.67	229.98
Coef of Variation	334.36	336.82	335.11	331.00	335.64	332.86	363.20	370.79	366.40	92.49	98.98	99.58	105.87
N=26 contracts n=213 reports													

SPACE CONTRACTS

not OTB all N=263 contracts n=3651 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	-2.40	-2.62	-2.65	-2.39	-2.38	-2.38	-1.04	-1.13	-1.08	318.23	295.68	218.47	231.92
SD	22.08	20.63	21.30	19.85	19.87	19.86	22.11	21.04	21.67	469.70	451.04	362.62	384.07
Coef of Variation	888.23	786.58	836.85	828.29	843.28	836.18	2131.33	1869.00	2003.13	147.14	152.54	165.94	165.80

not OTB early N=263 contracts n=272 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	-7.69	-8.29	-8.39	-7.61	-7.89	-7.76	-2.37	-4.17	-3.18	338.71	279.08	75.89	81.17
SD	47.13	38.92	41.99	30.32	30.28	30.26	46.94	39.11	43.20	430.48	363.86	104.92	112.82
Coef of Variation	612.50	367.50	500.34	398.31	383.36	390.03	1984.46	937.66	1368.53	127.09	130.38	138.28	139.00

not OTB middle N=263 contracts n=993 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	-9.07	-9.10	-9.08	-8.14	-8.04	-8.09	-6.47	-6.37	-6.42	295.59	259.40	143.70	151.28
SD	23.00	23.19	23.08	23.83	23.86	23.86	23.83	24.19	23.98	412.61	373.25	214.36	228.28
Coef of Variation	253.87	254.98	263.92	292.72	297.04	294.89	368.32	379.86	373.41	139.59	143.89	149.17	150.91

not OTB late N=263 contracts n=2286 reports	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	1.00	0.98	0.99	0.72	0.77	0.74	1.58	1.61	1.59	327.18	313.43	267.91	284.27
SD	16.17	16.14	16.16	16.14	16.16	16.16	16.24	16.24	16.24	496.50	498.64	419.09	443.58
Coef of Variation	1621.07	1540.49	1632.26	2089.83	1967.26	2034.47	1029.88	1008.88	1021.11	151.75	156.96	156.43	156.04

NOT OTB CONTRACTS

OTB all	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	-2.93	-2.20	-2.11	-2.66	-2.60	-2.56	-0.56	-0.70	-0.64	273.78	244.83	180.58	181.70
SD	18.77	18.78	18.78	20.24	20.27	20.25	20.31	20.21	20.26	404.22	368.90	298.81	309.97
Coef of Variation	673.27	898.06	938.32	782.56	811.88	794.18	3703.87	2888.97	3162.90	147.64	150.71	164.28	161.89
N=88 contracts, n=282 reports													

OTB early	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	-1.77	-1.92	-1.93	0.07	0.42	0.27	3.03	3.20	3.06	208.53	182.73	50.47	53.13
SD	27.84	27.59	27.62	28.18	28.07	28.07	28.38	28.08	28.17	275.18	233.83	78.67	87.40
Coef of Variation	1567.99	1438.02	1433.22	43840.18	6908.11	10837.97	936.06	878.40	922.86	131.96	127.96	155.89	164.50
N=88 contracts, n=30 reports													

OTB middle	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	-4.46	-4.93	-4.61	-6.08	-6.14	-6.10	-2.18	-2.74	-2.62	229.69	200.91	110.18	117.56
SD	26.10	26.09	25.10	25.48	25.67	25.63	26.18	25.99	26.09	398.51	357.86	196.48	204.26
Coef of Variation	583.96	510.26	544.72	420.22	418.62	412.81	1197.69	948.85	1035.78	173.94	178.12	178.34	173.78
N=88 contracts, n=80 reports													

OTB late	%dev EAC1	%dev EAC2	%dev EAC3	%dev EAC4	%dev EAC5	%dev EAC6	%dev EAC7	%dev EAC8	%dev EAC9	CAC	TAB	BCWP	ACWP
MEAN	-0.72	-0.76	-0.74	-1.13	-1.08	-1.10	-0.38	-0.37	-0.36	312.42	282.80	247.70	262.75
SD	13.45	13.47	13.46	13.42	13.41	13.42	13.46	13.46	13.46	427.02	394.90	350.38	366.76
Coef of Variation	1869.64	1733.49	1823.83	1187.49	1261.71	1222.83	3510.81	3665.00	3710.00	136.68	139.72	141.46	139.21
N=88 contracts, n=142 reports													

OTB CONTRACTS

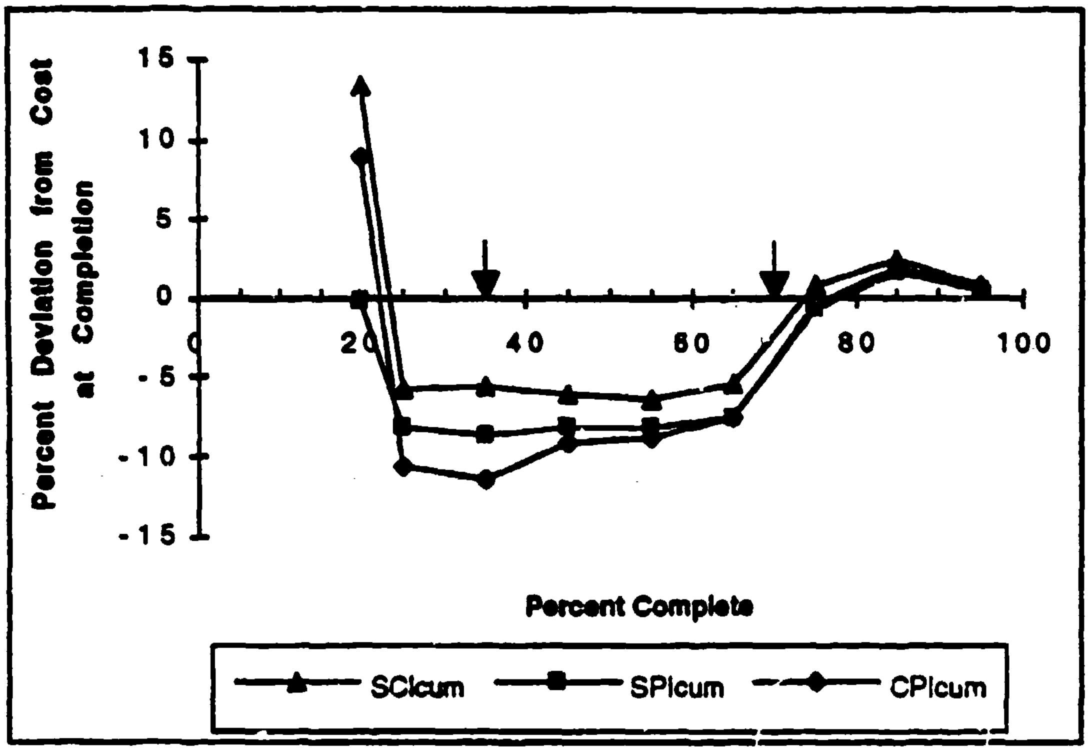
Appendix D: EAC and Index Ceiling and Floor Graphs

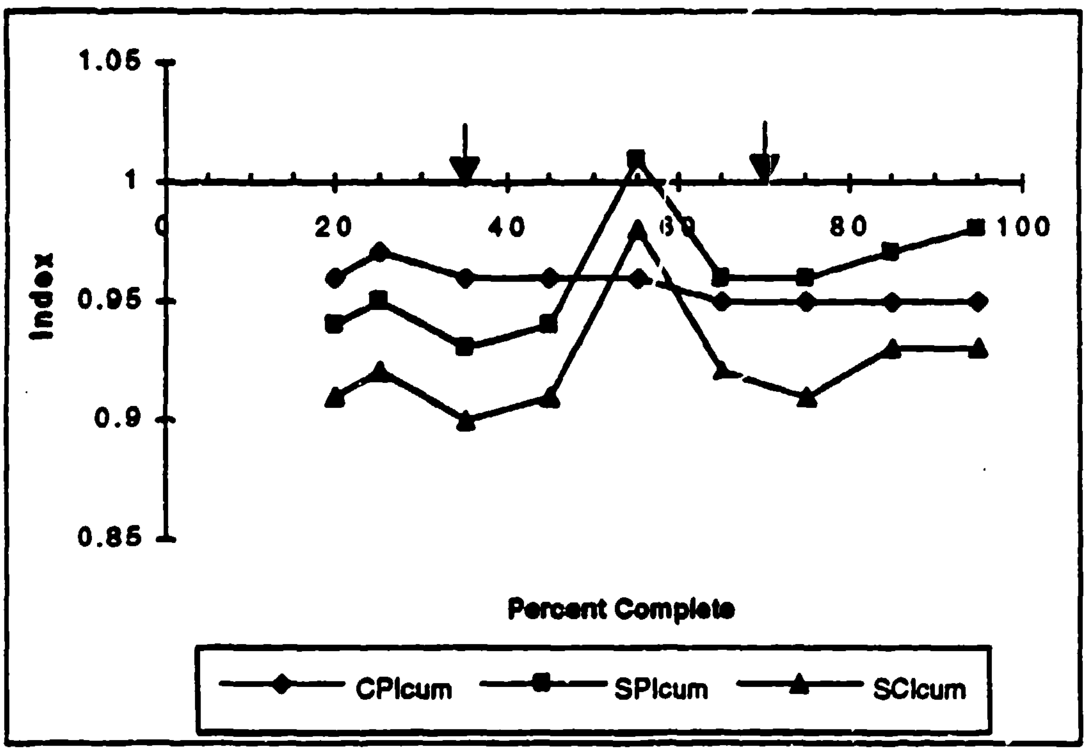
This appendix presents graphs of EACs and their corresponding indexes. Each page contains two graphs. The top graph presents EAC average percent deviation from cost at completion. The bottom graph presents the indexes that correspond to each EAC in the preceding graph.

The **arrows on the horizontal axes** (X axis-Percent Complete) represent transition points between Early, Middle and Late Contract Completion Stages. Specifically:

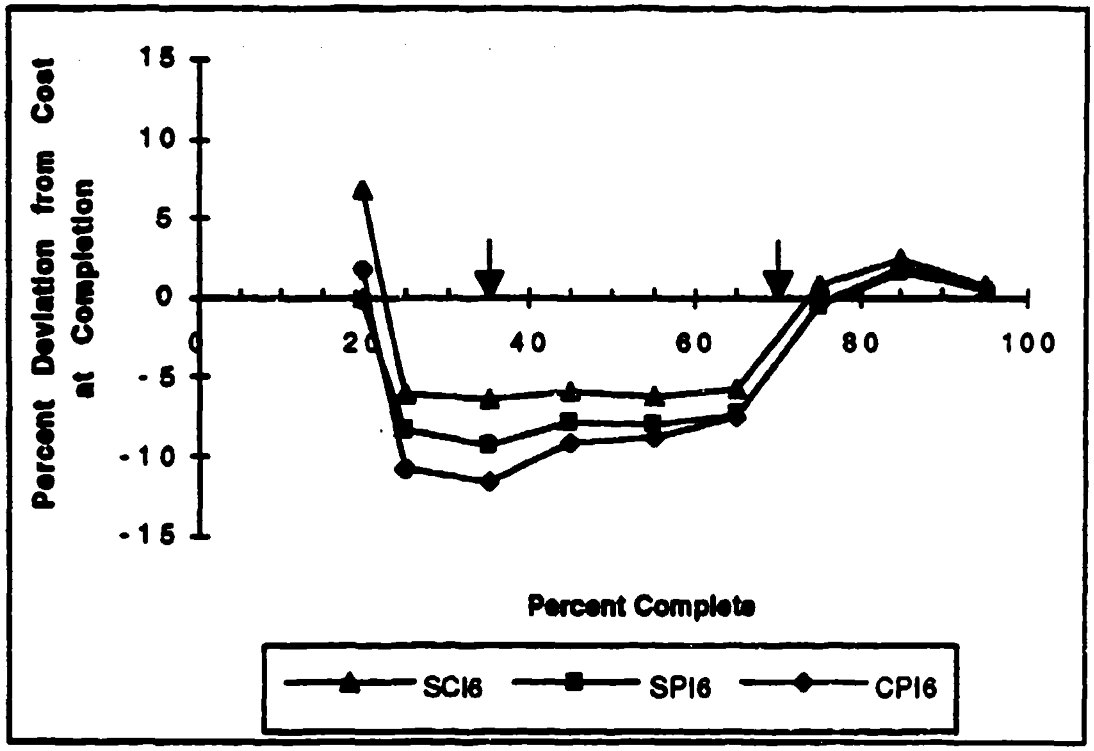
Early: Contract Percent Complete < .35
Middle: .35 < Contract Percent Complete <= .70
Late: Contract Percent Complete > .70

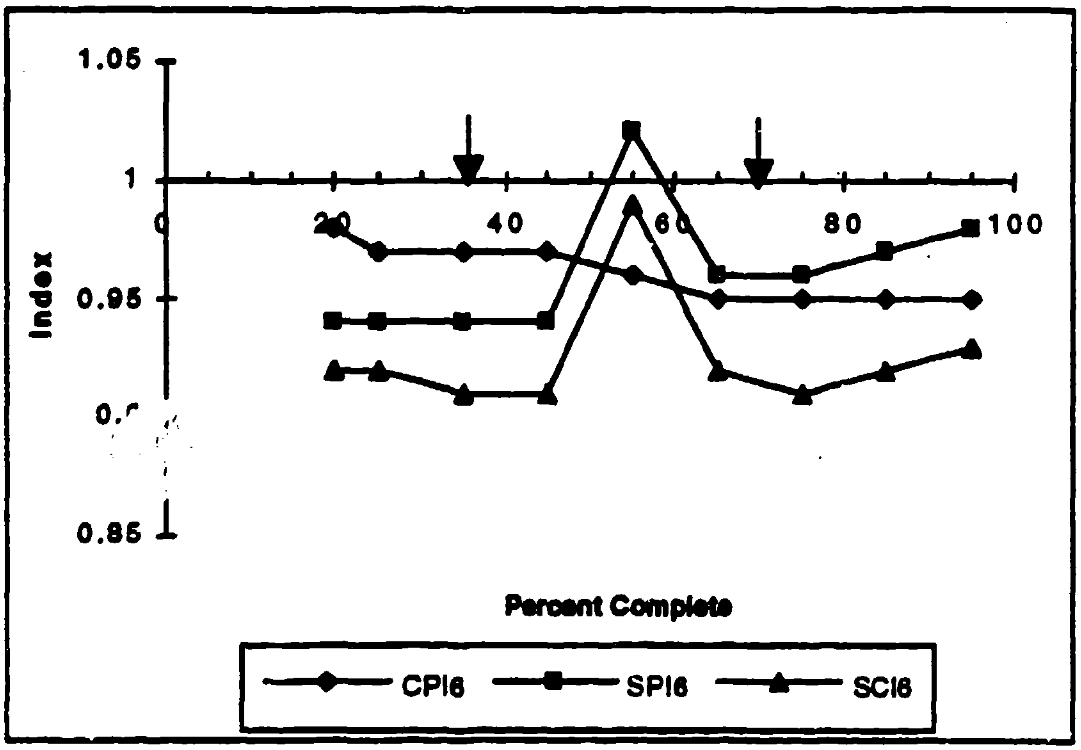
The first six pages present results based upon each index type (cumulative, six-month and three-month). The first three pages represent all contracts (cumulative, six-month and three-month). The next three pages represent all contracts with Management Reserve removed. The remaining graphs present the EAC ceiling and floor and their corresponding indexes for each category.



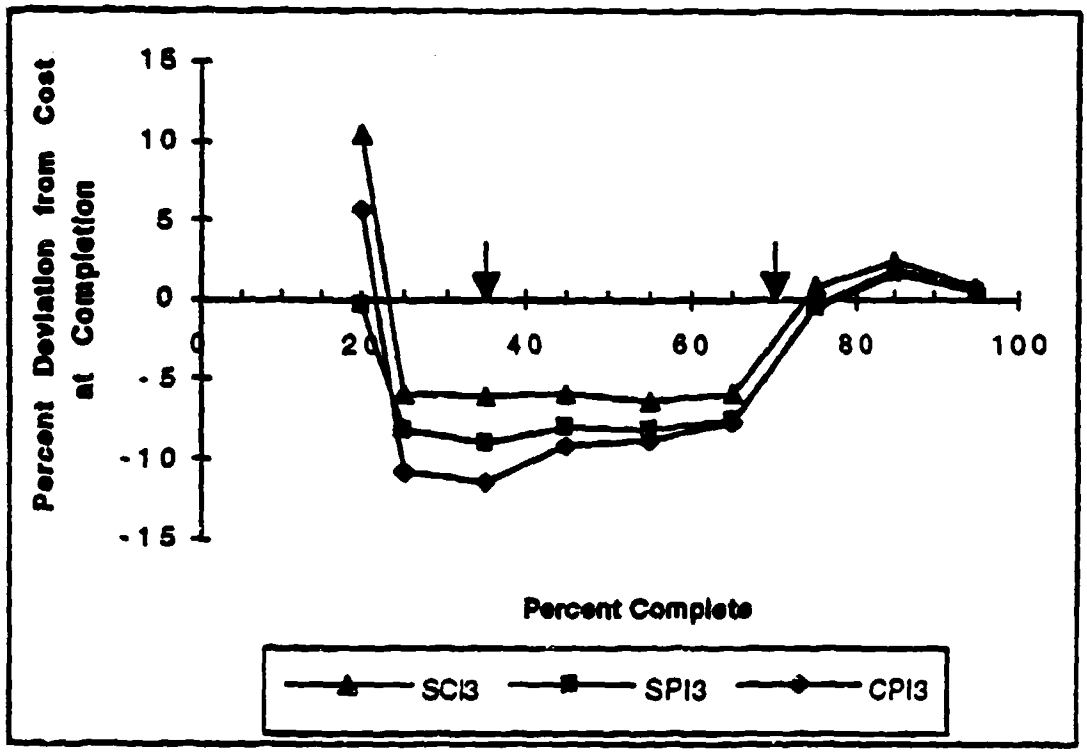


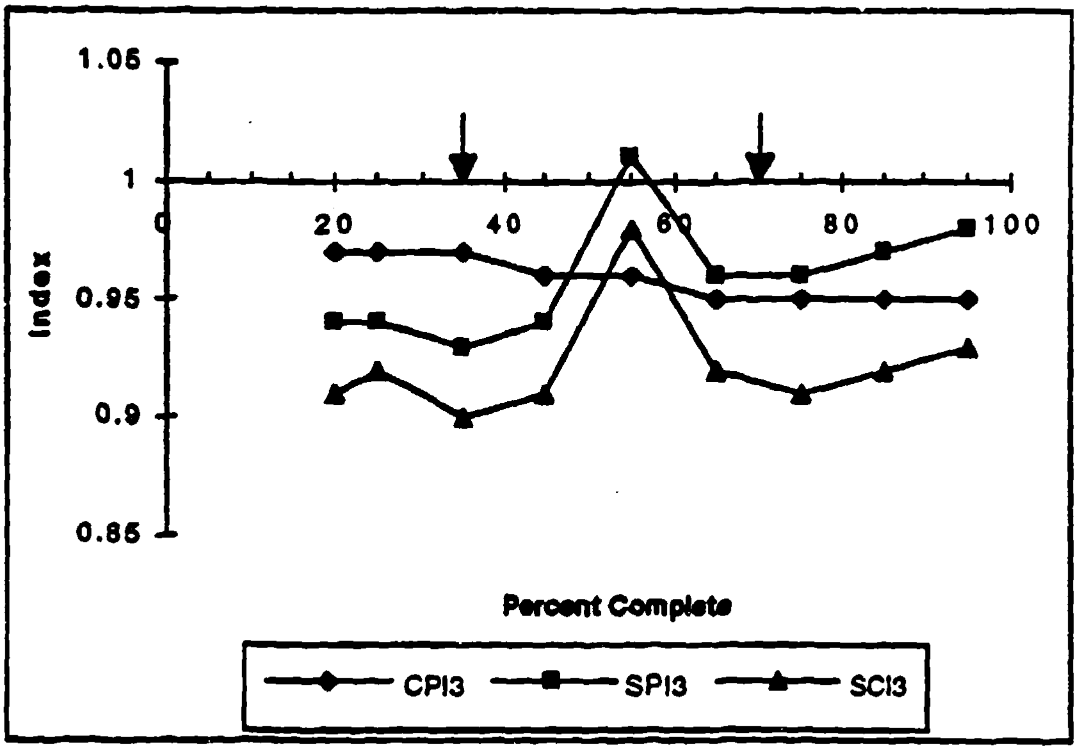
ALL CONTRACTS CUMULATIVE EAC & INDEX GRAPHS



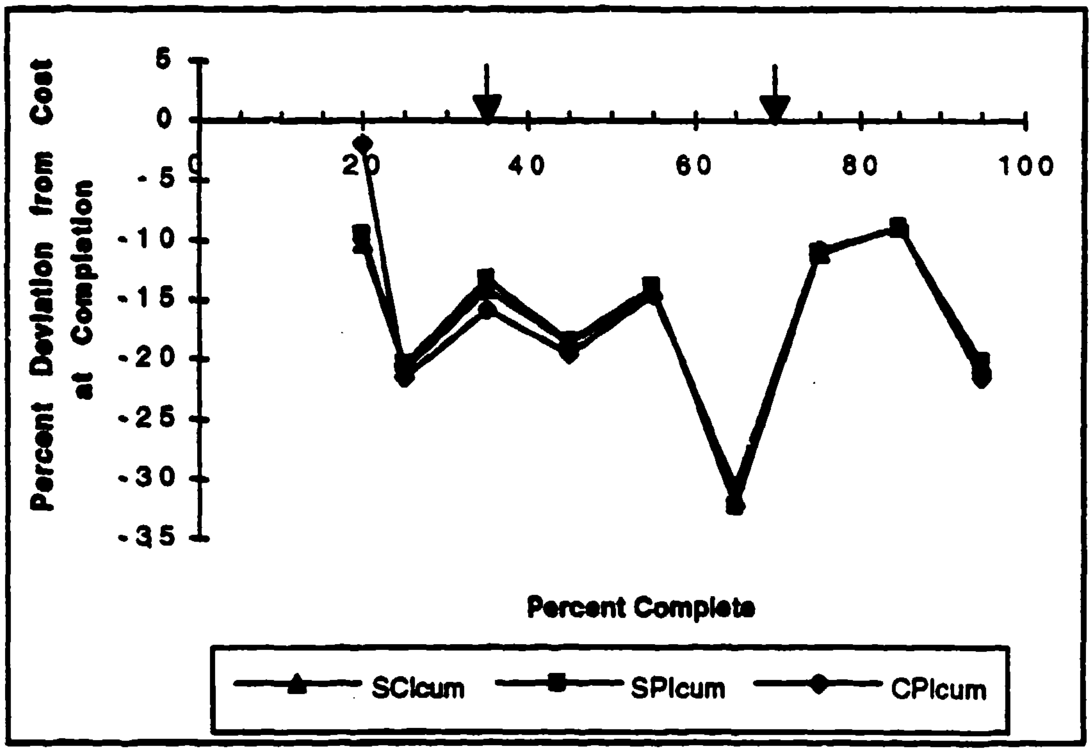


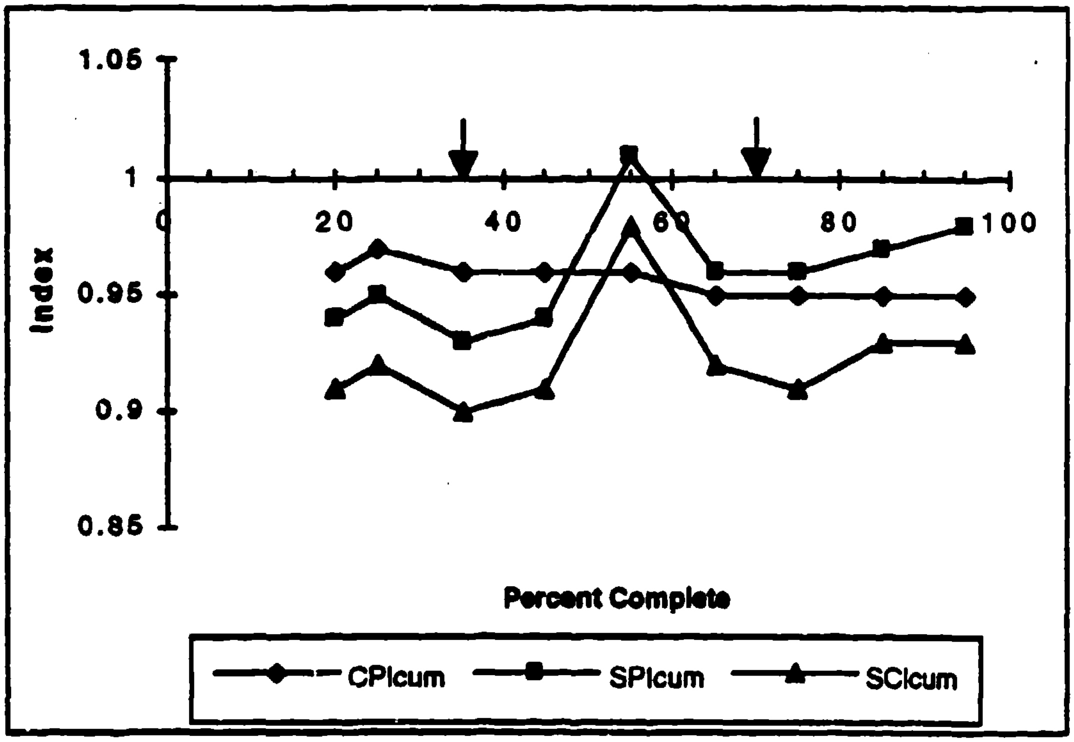
ALL CONTRACTS SIX-MONTH EAC & INDEX GRAPHS



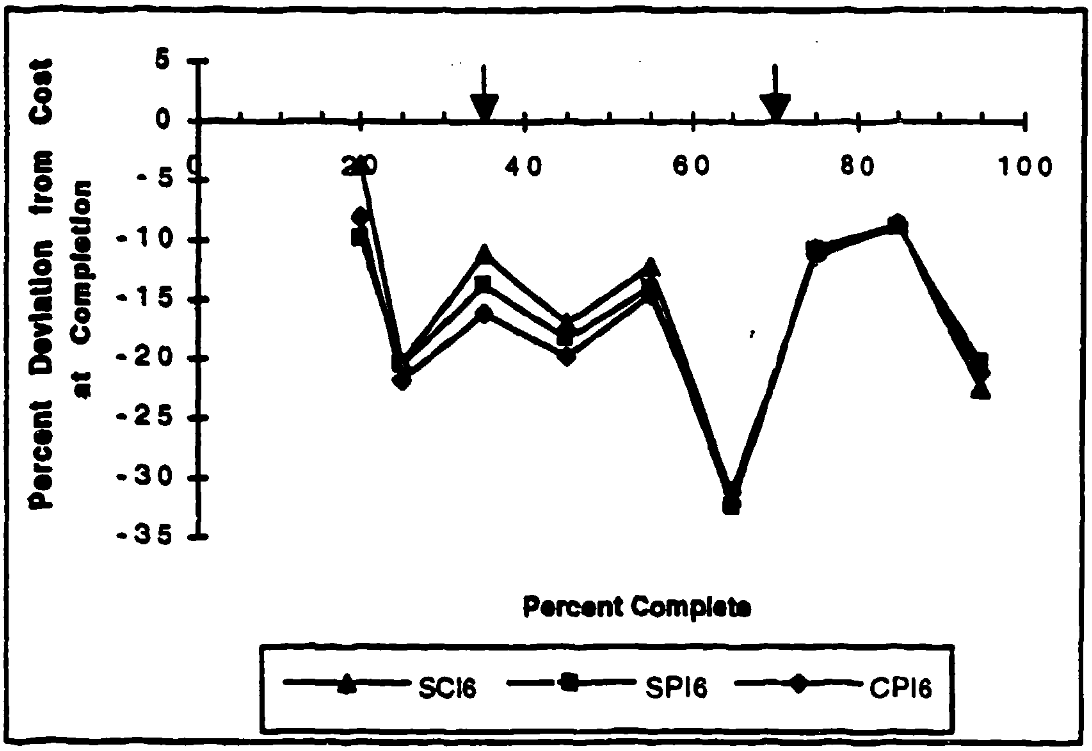


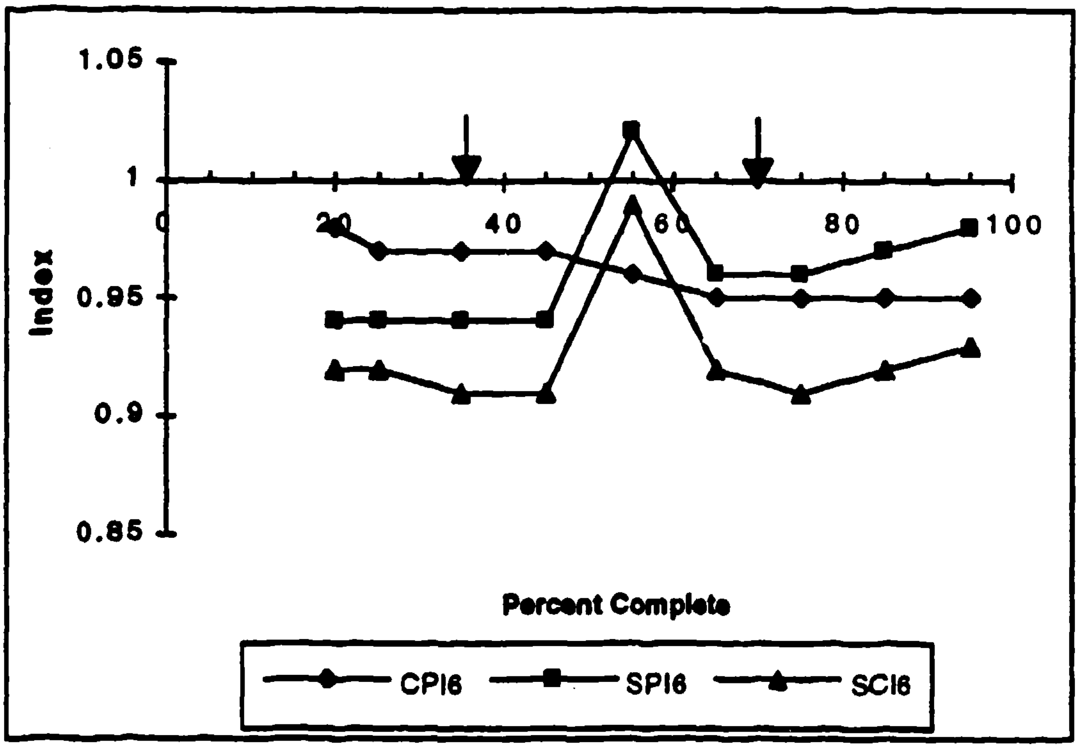
ALL CONTRACTS THREE-MONTH EAC & INDEX GRAPHS



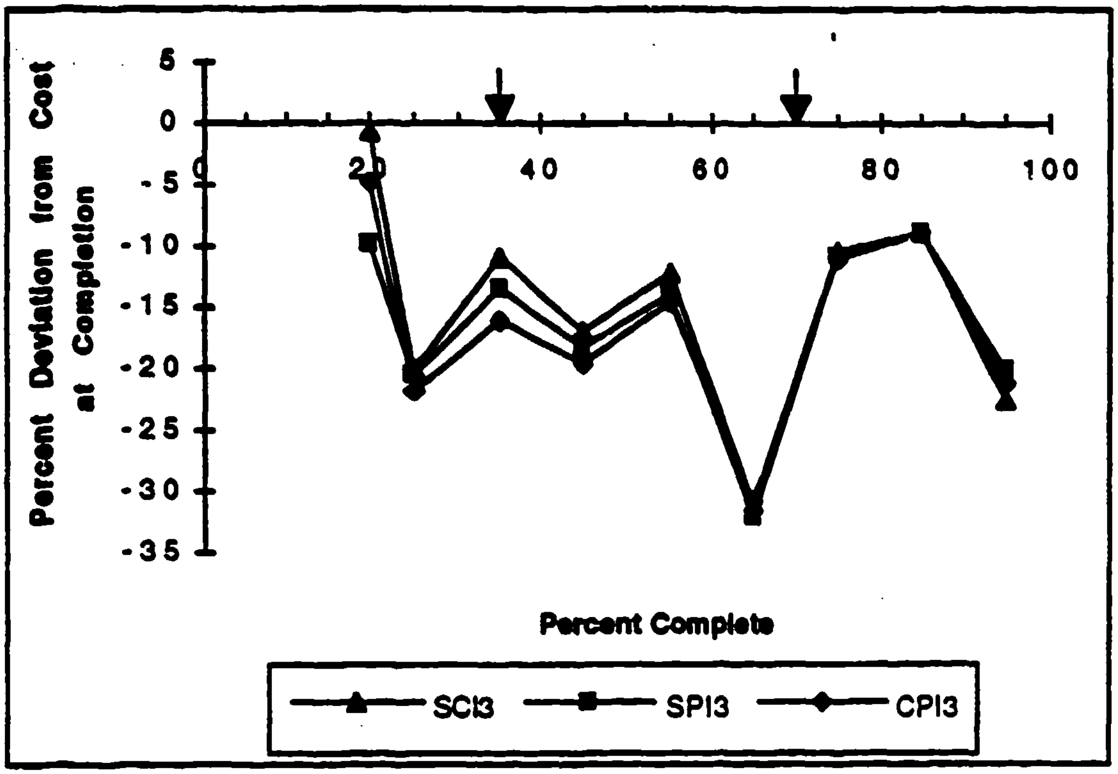


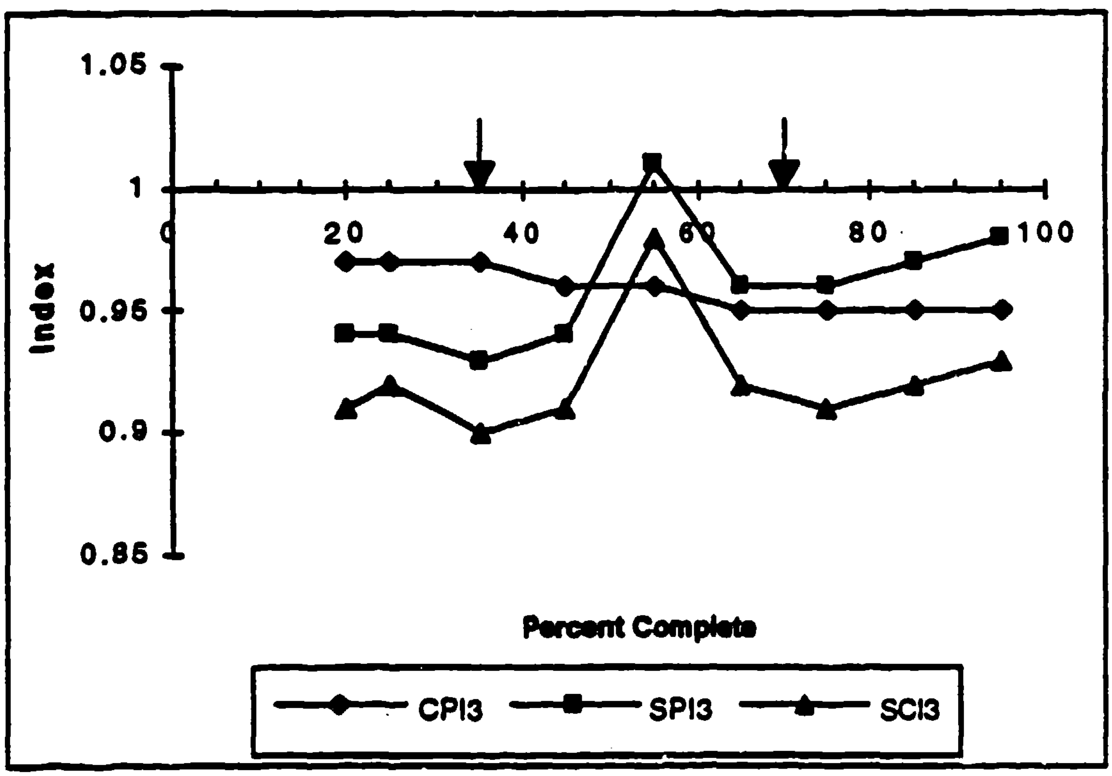
ALL CONTRACTS (MR REMOVED) CUMULATIVE EAC & INDEX GRAPHS





ALL CONTRACTS (MR REMOVED) SIX-MONTH EAC & INDEX GRAPHS





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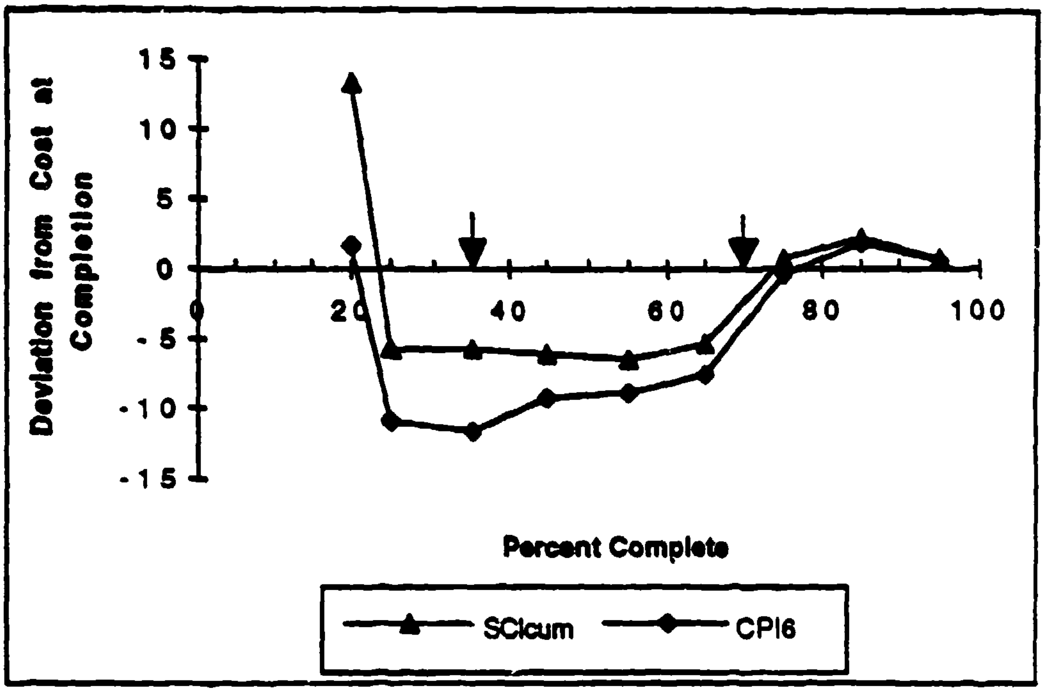

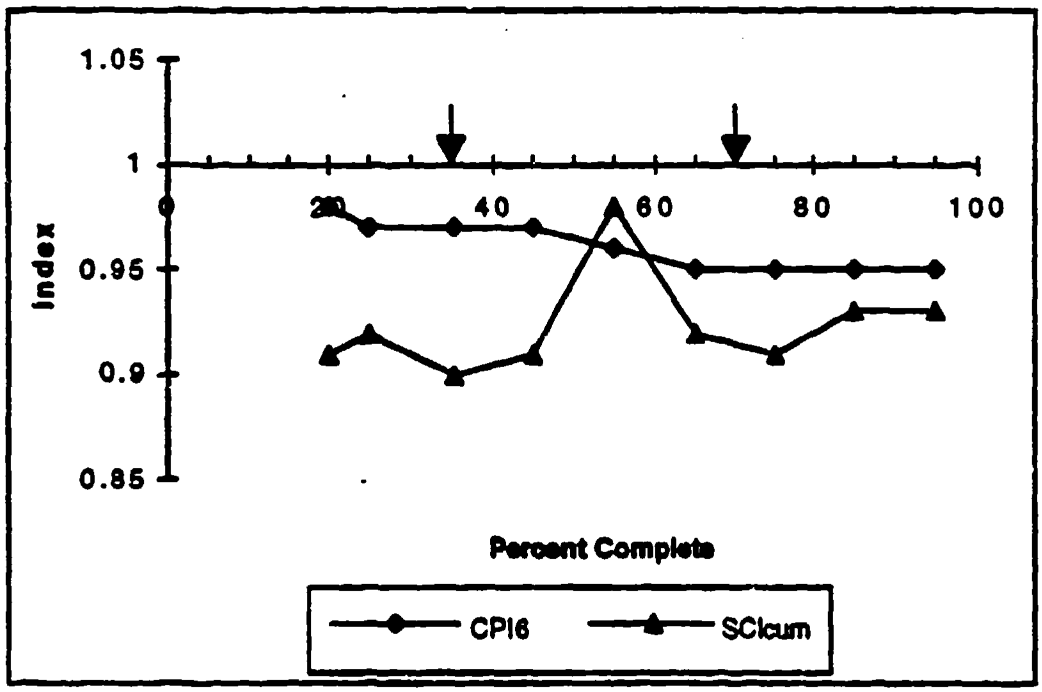

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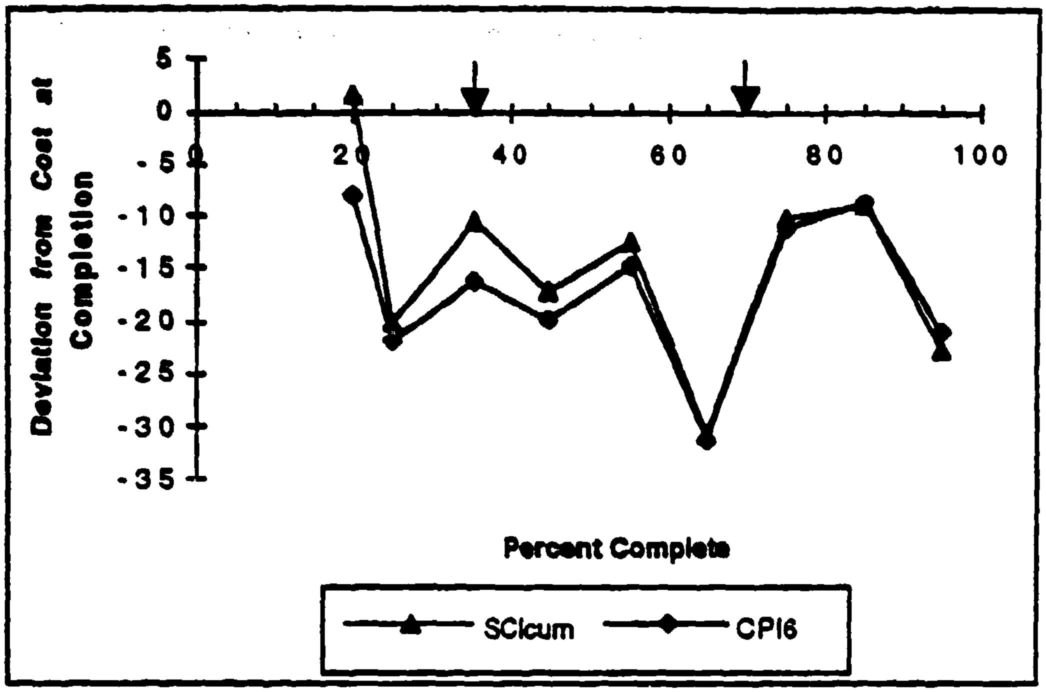

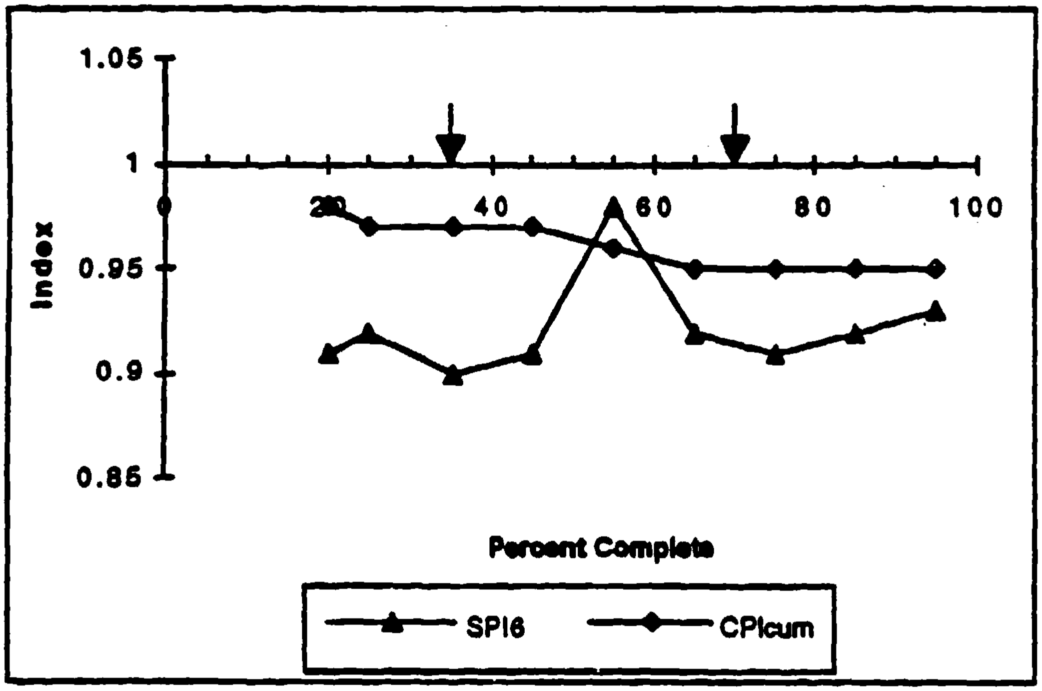

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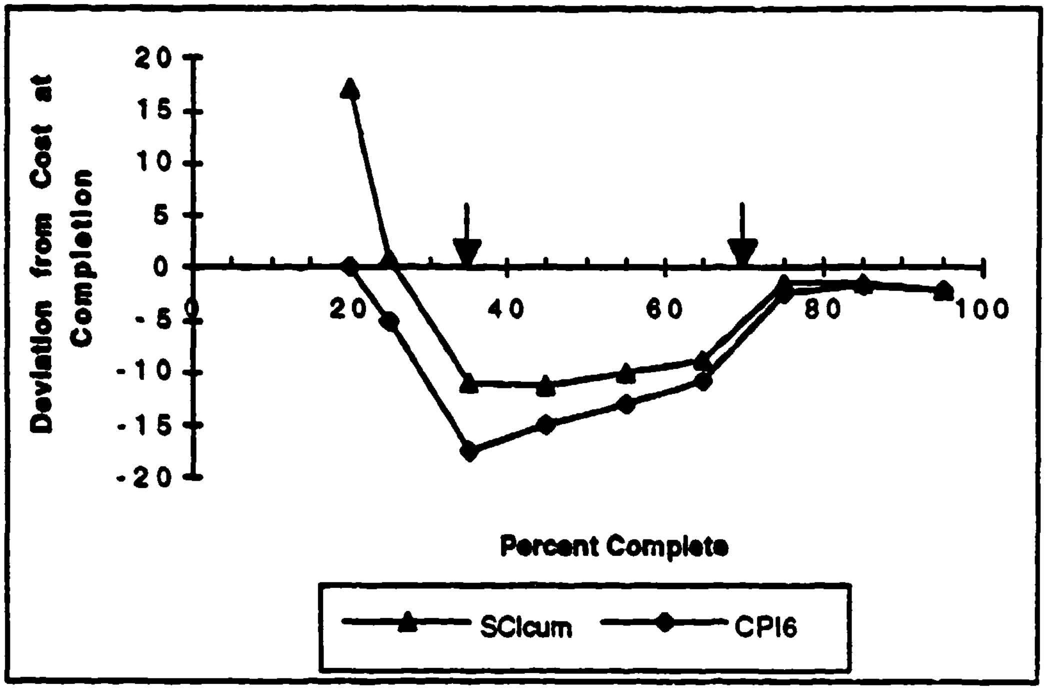

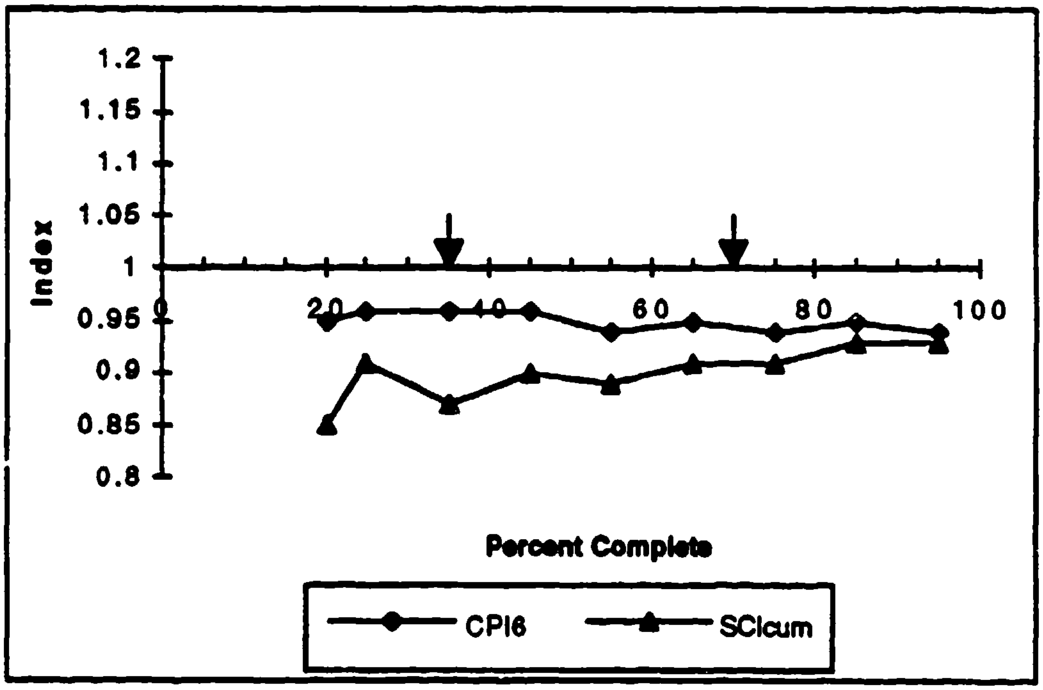

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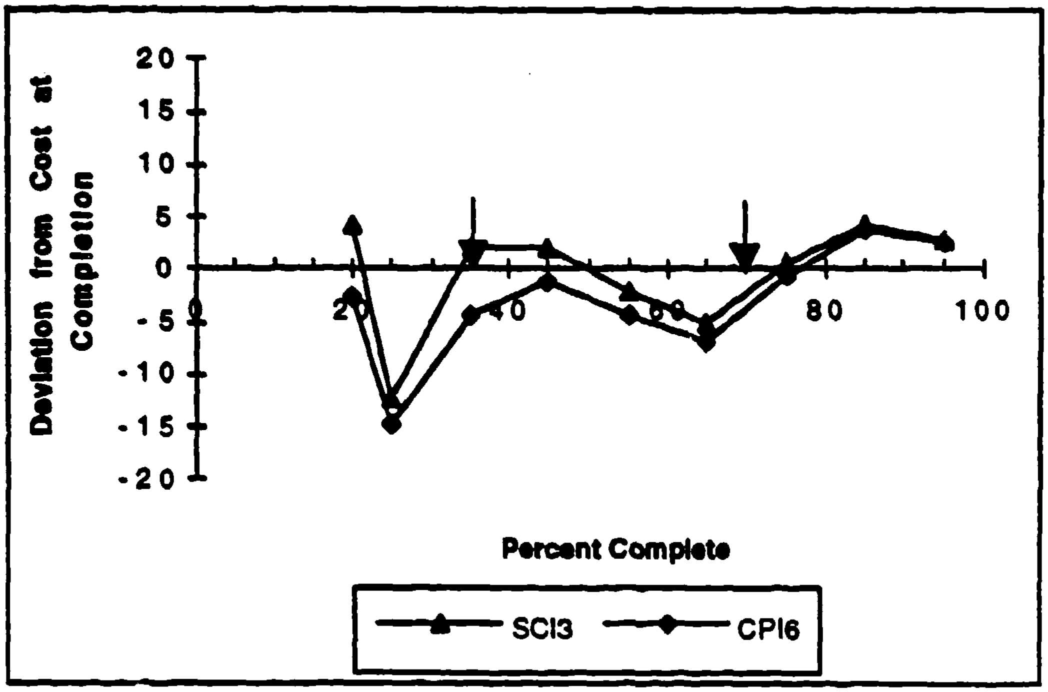

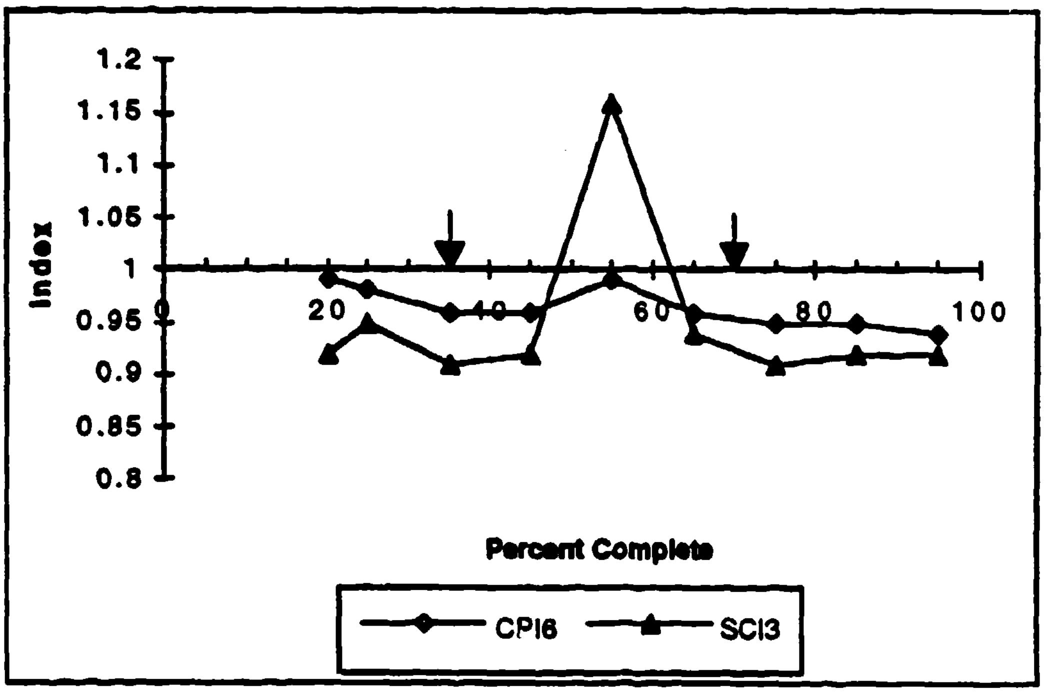

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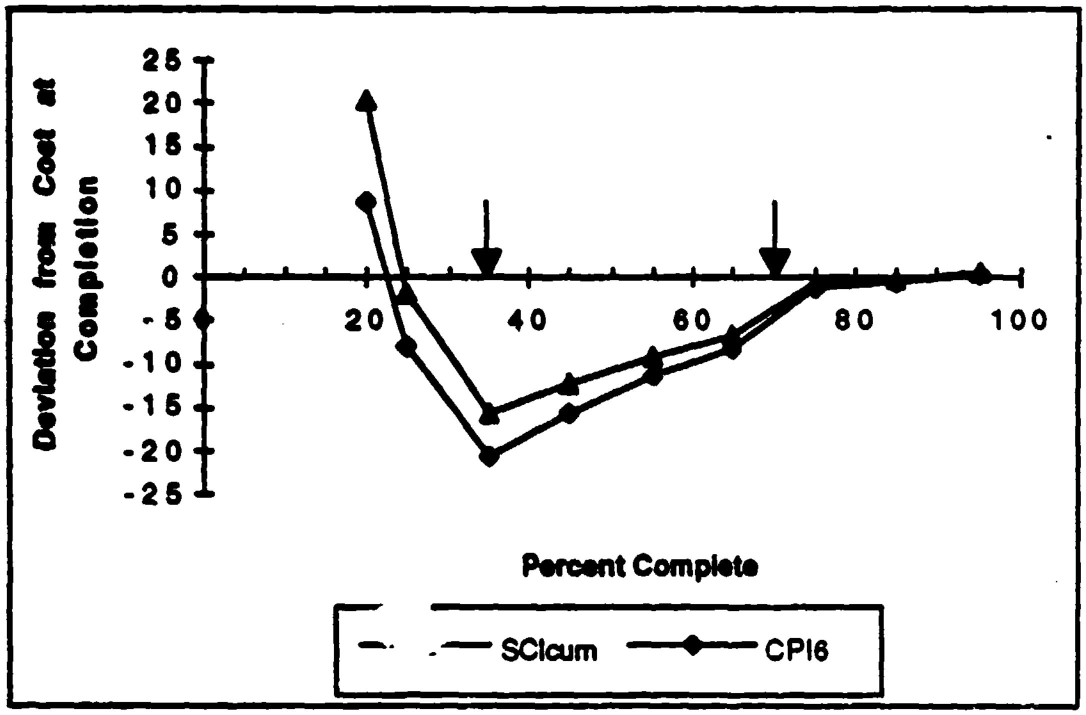

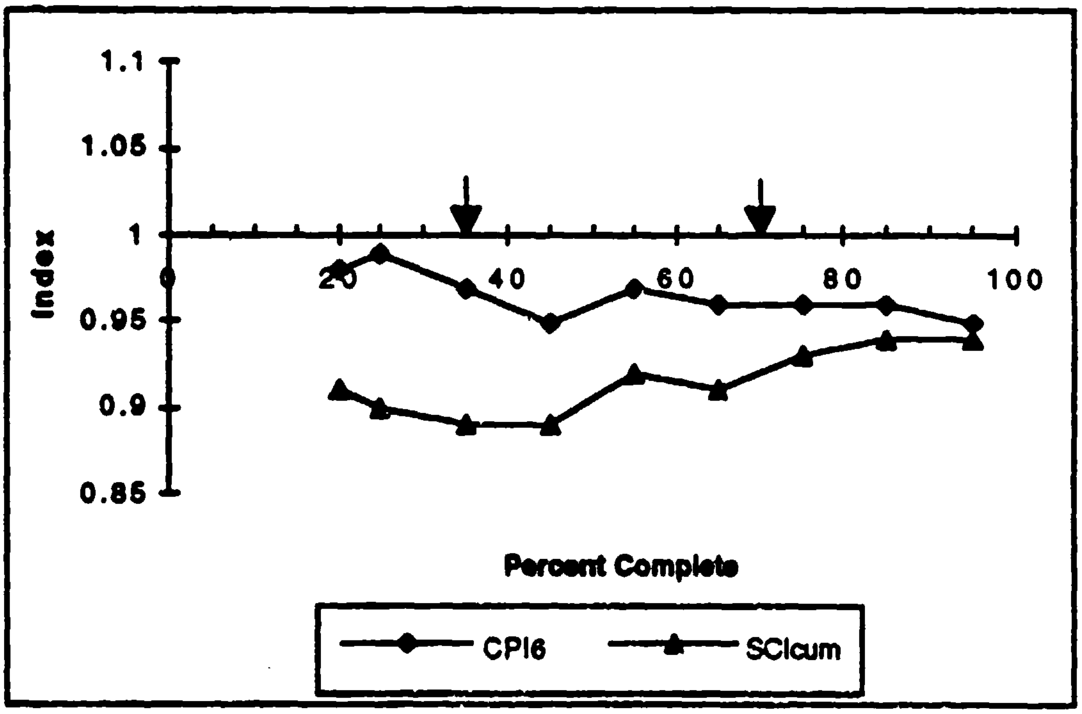

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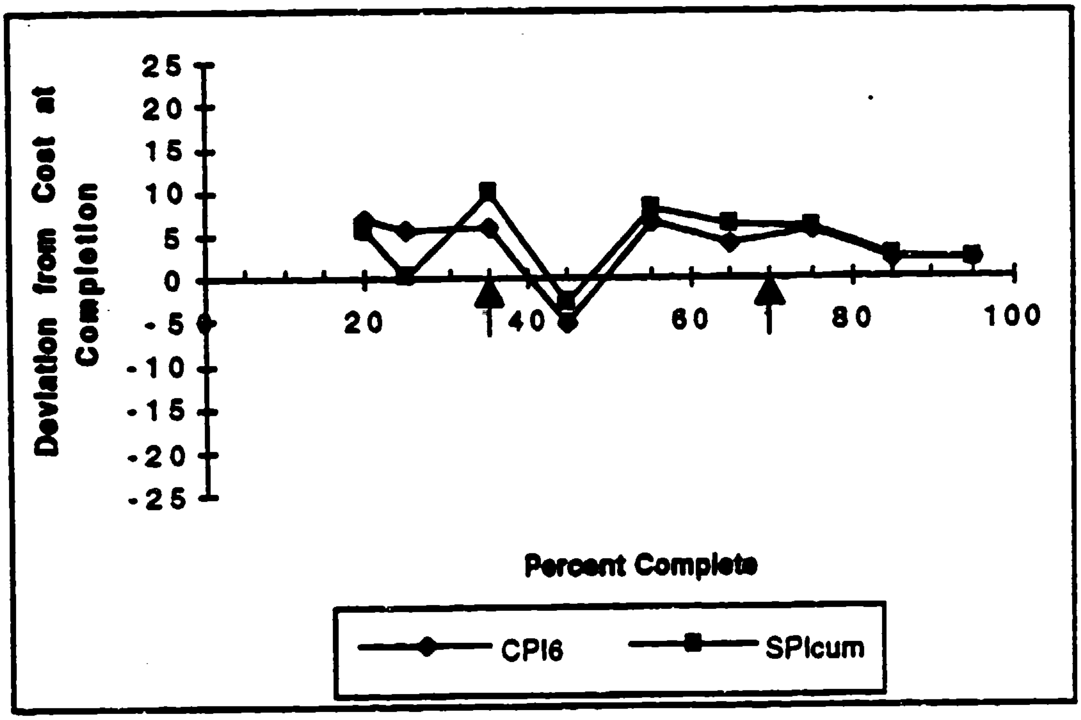

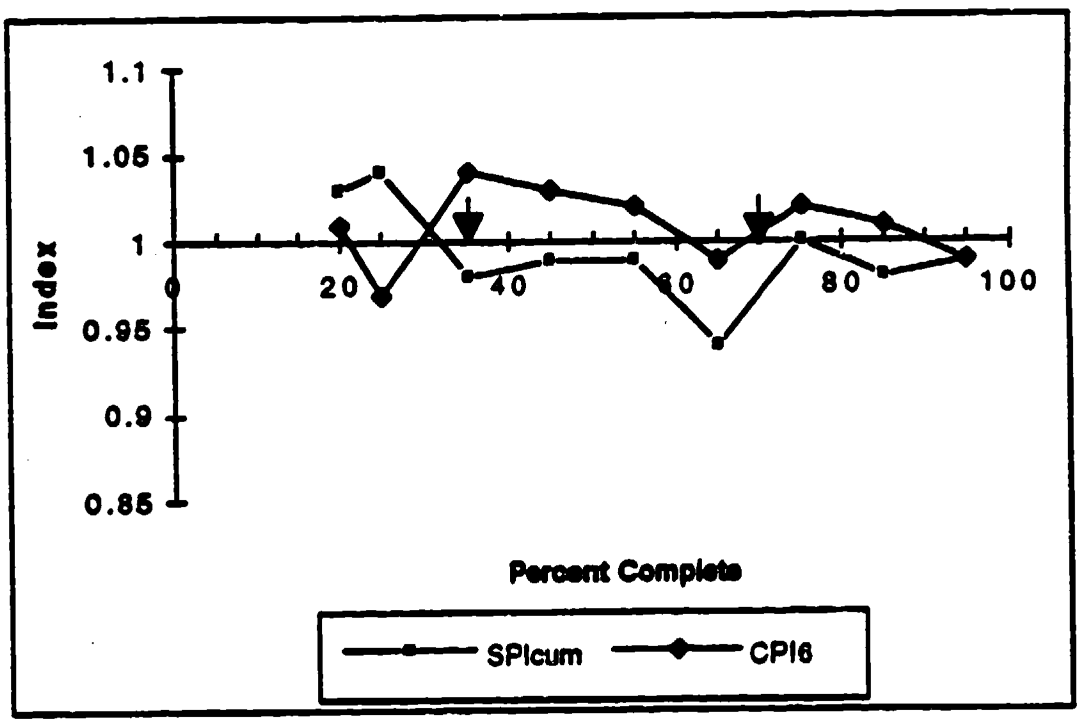

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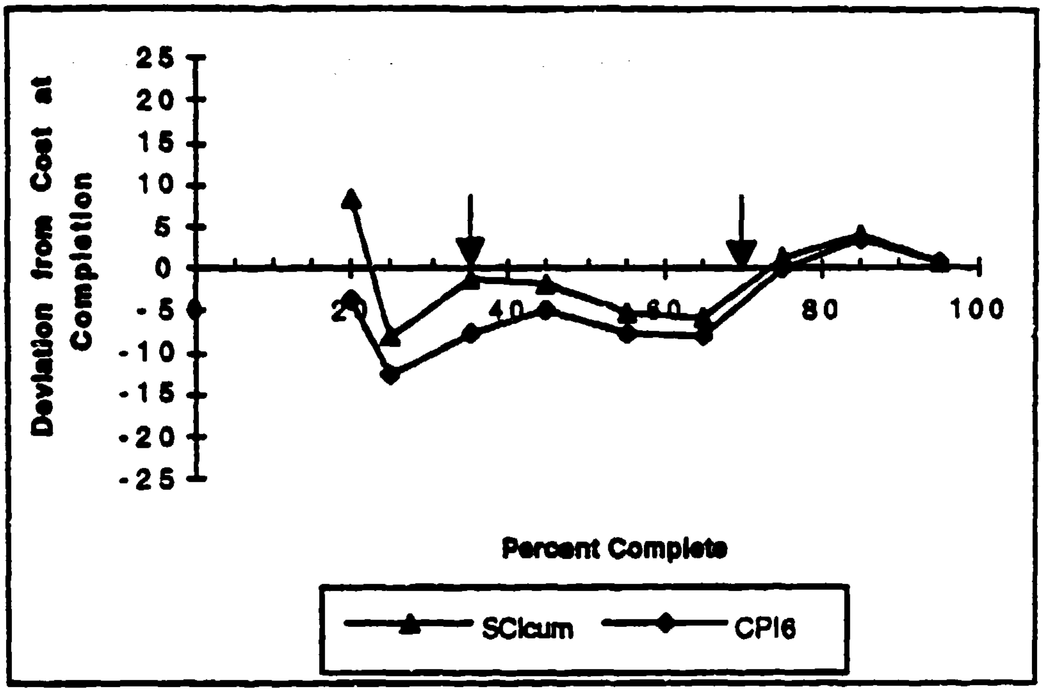

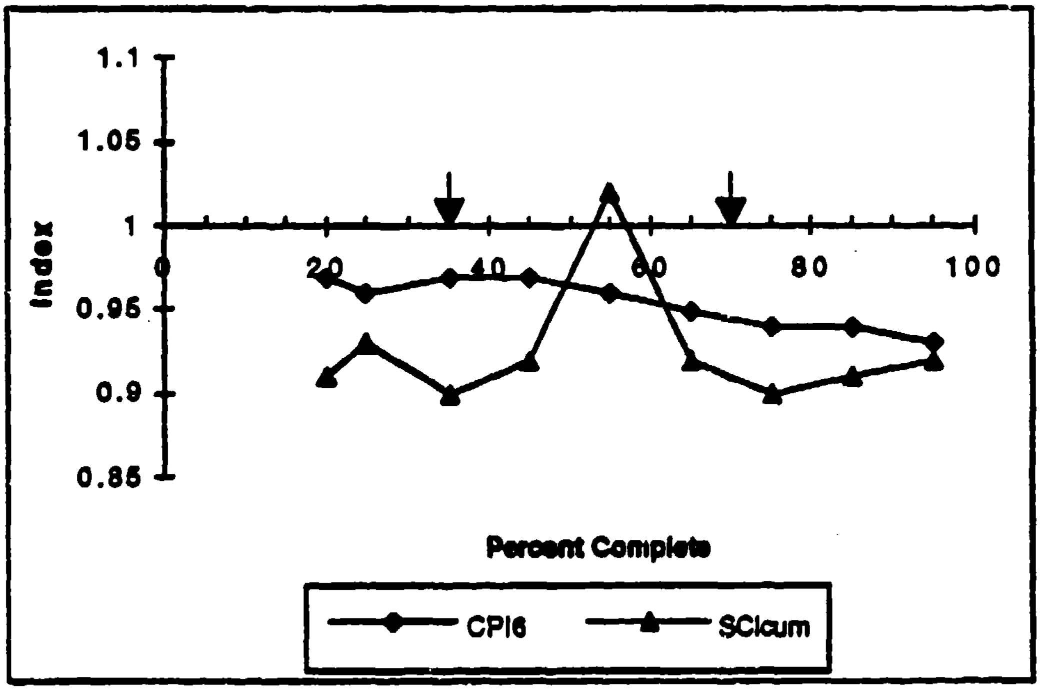

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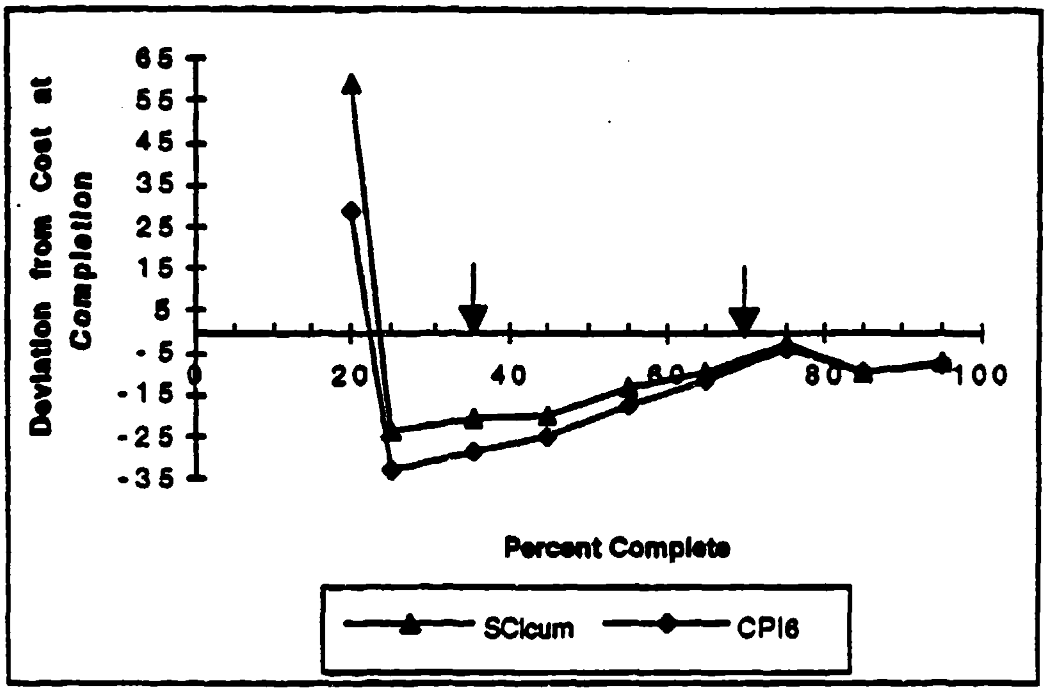

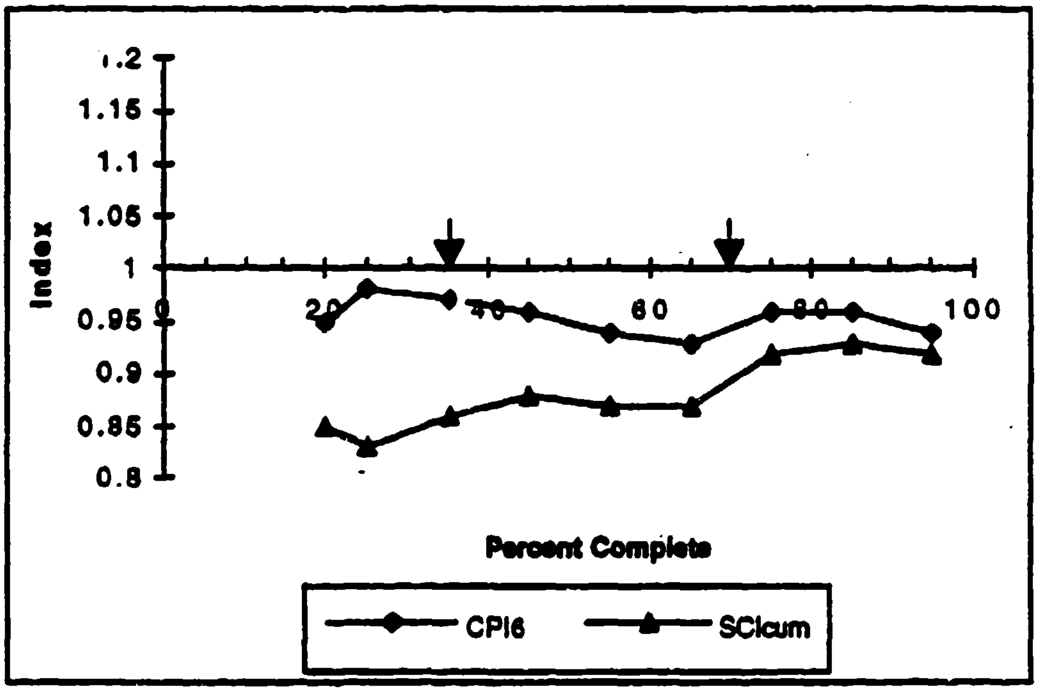

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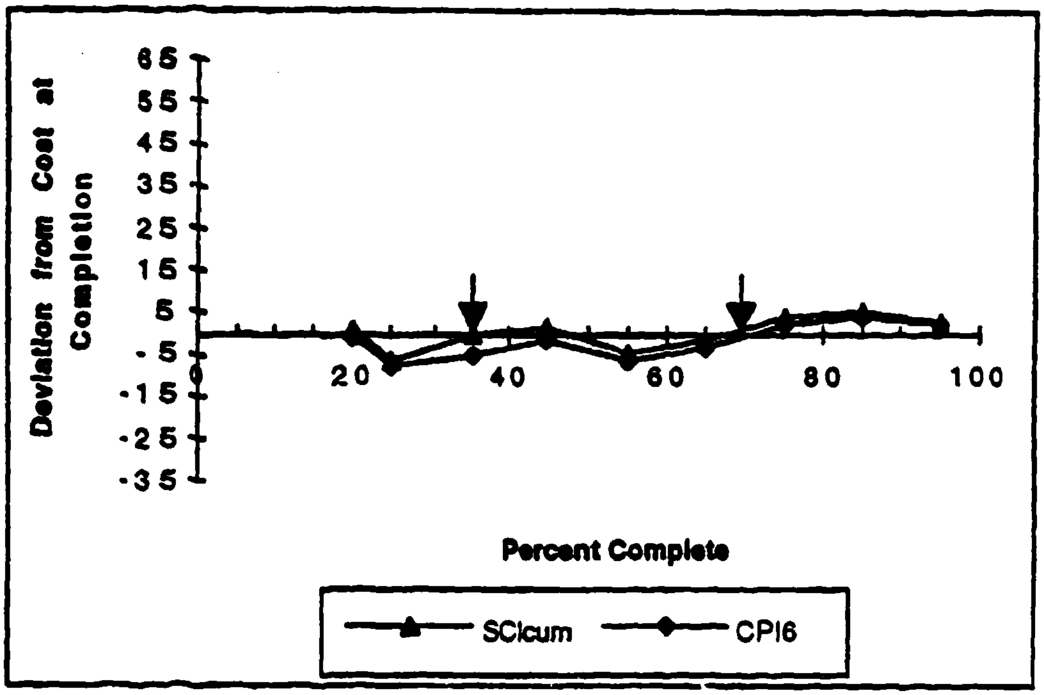

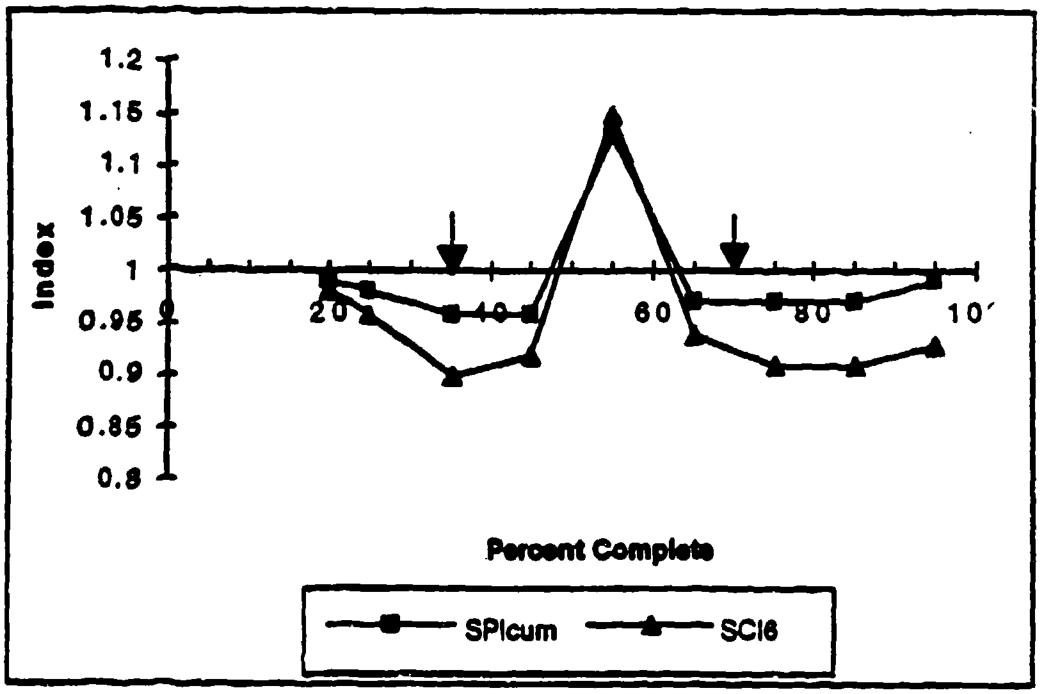

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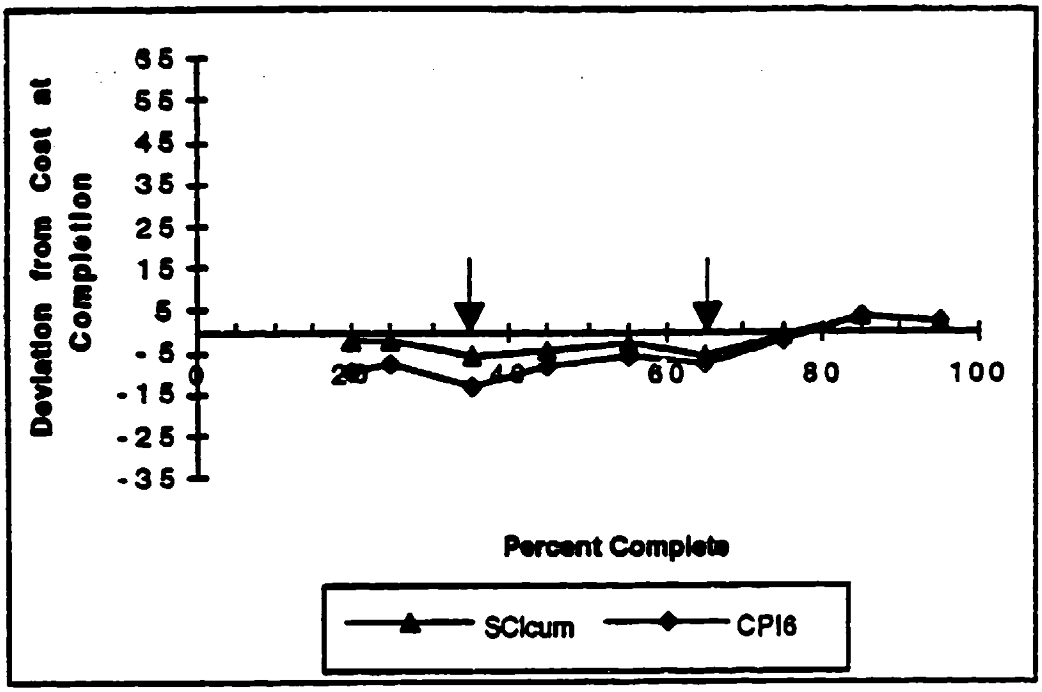

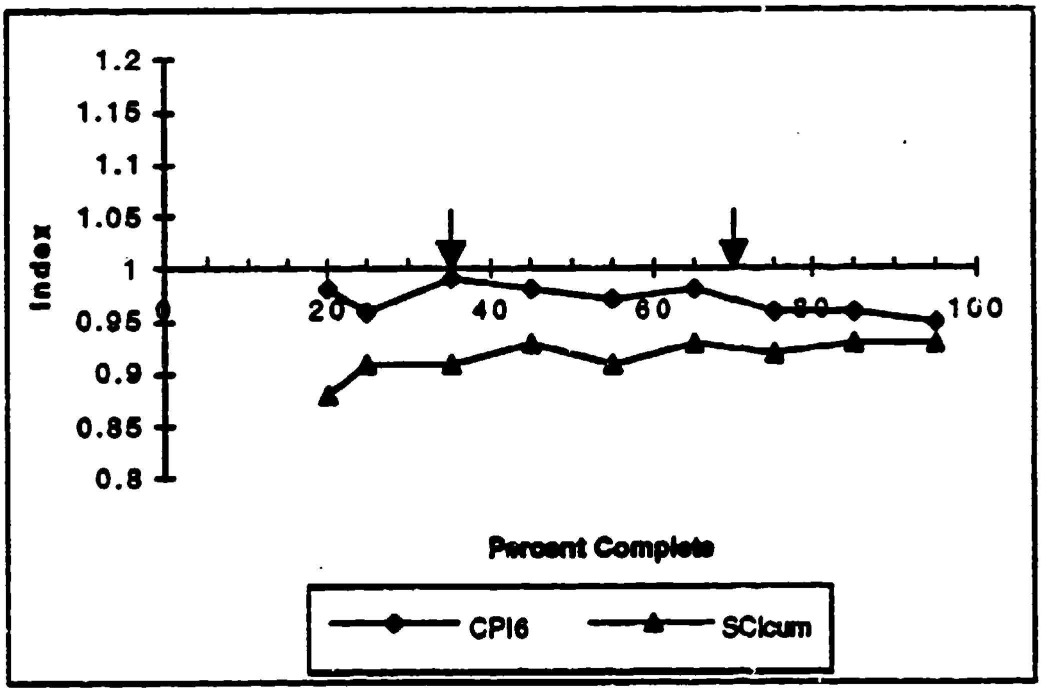

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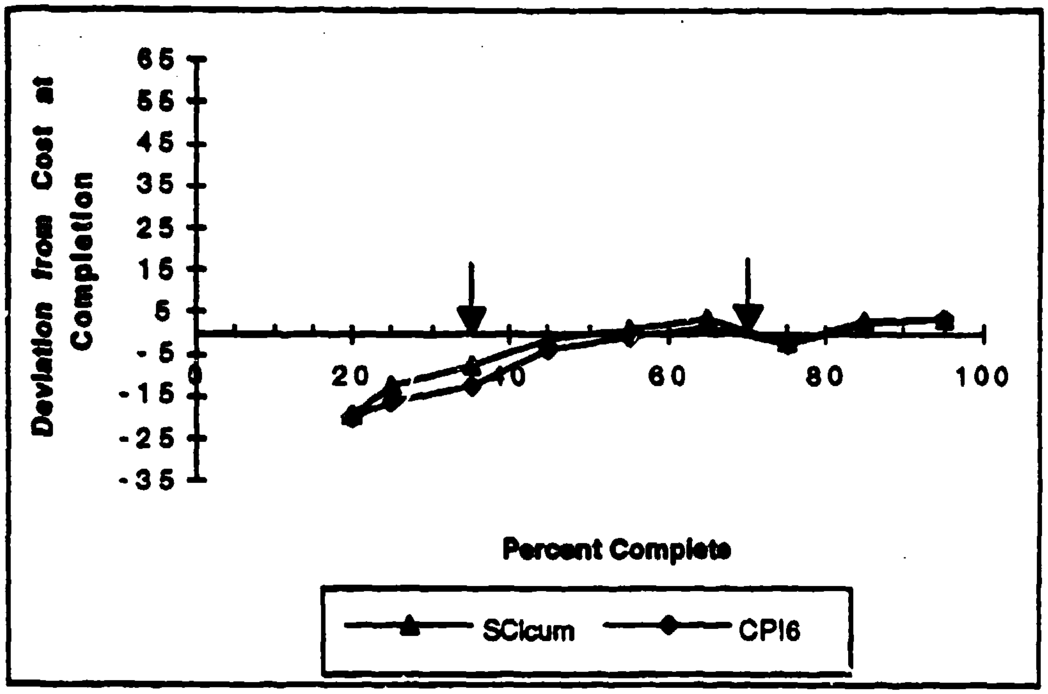

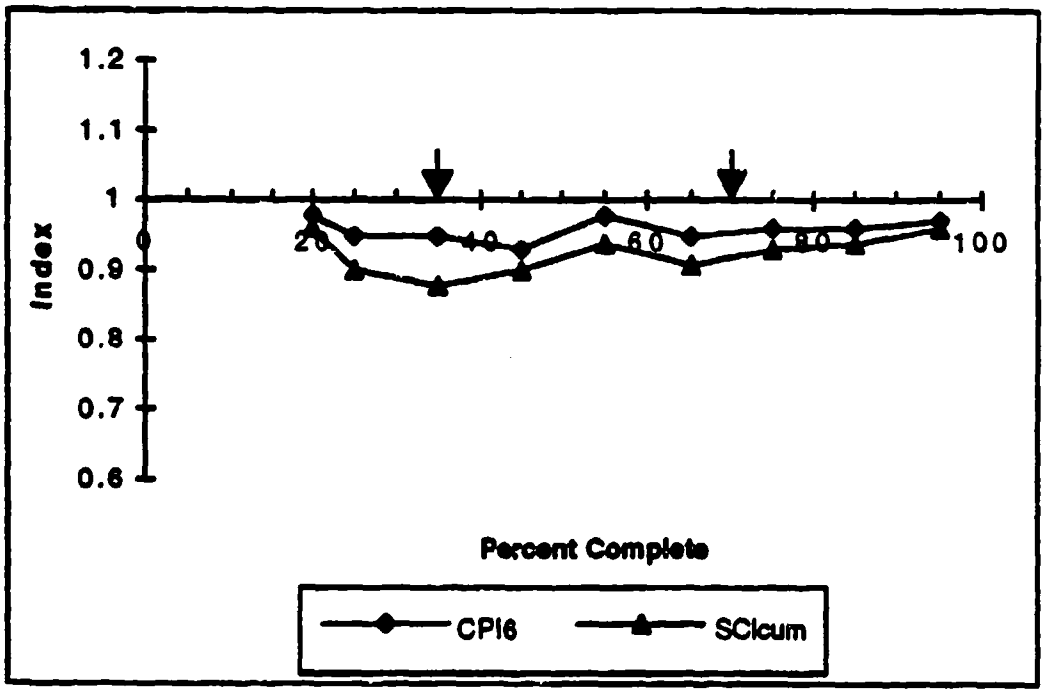

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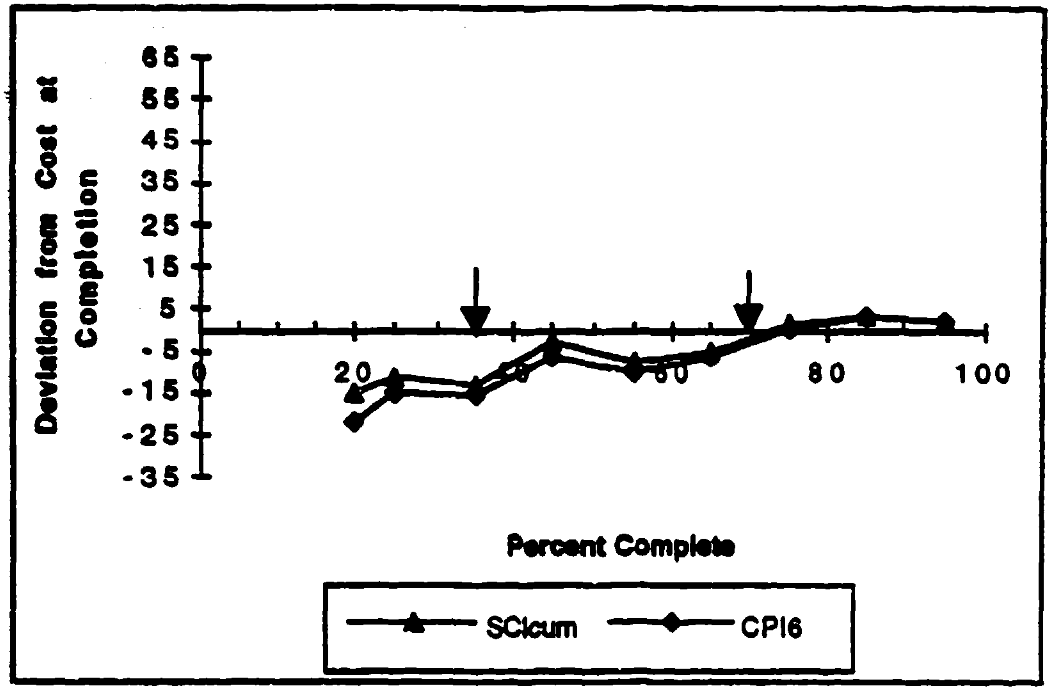

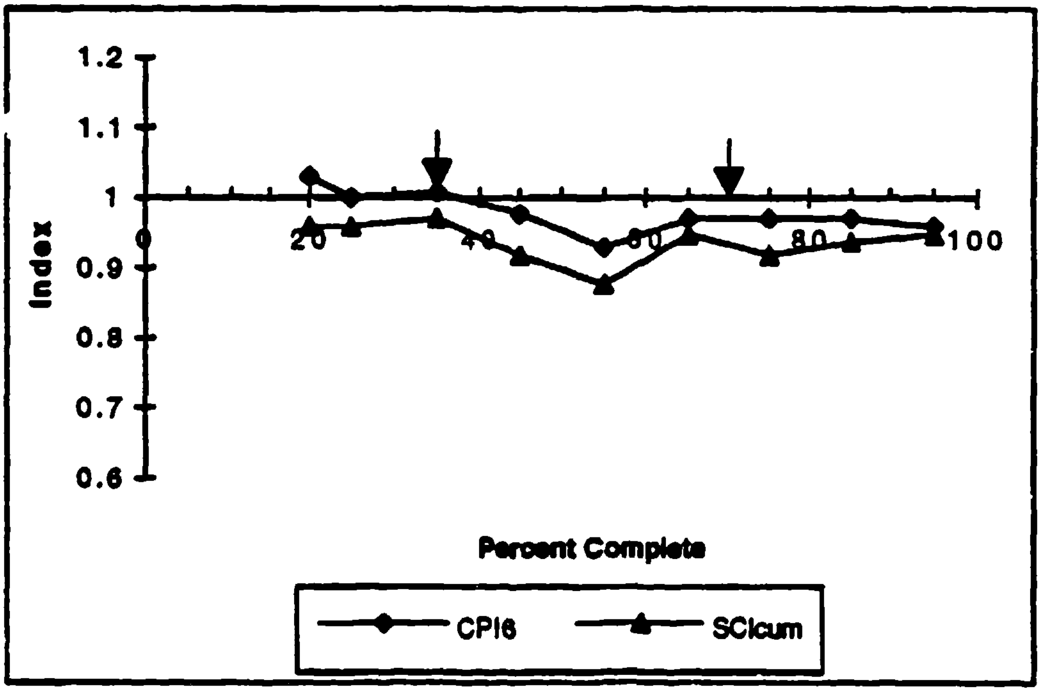

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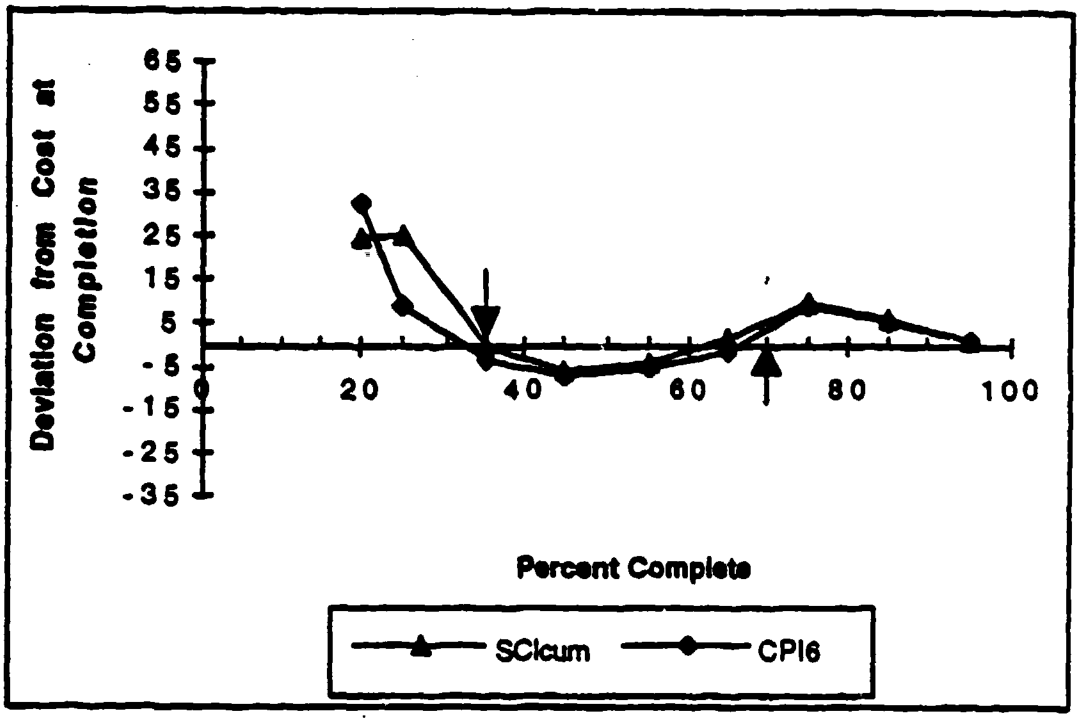

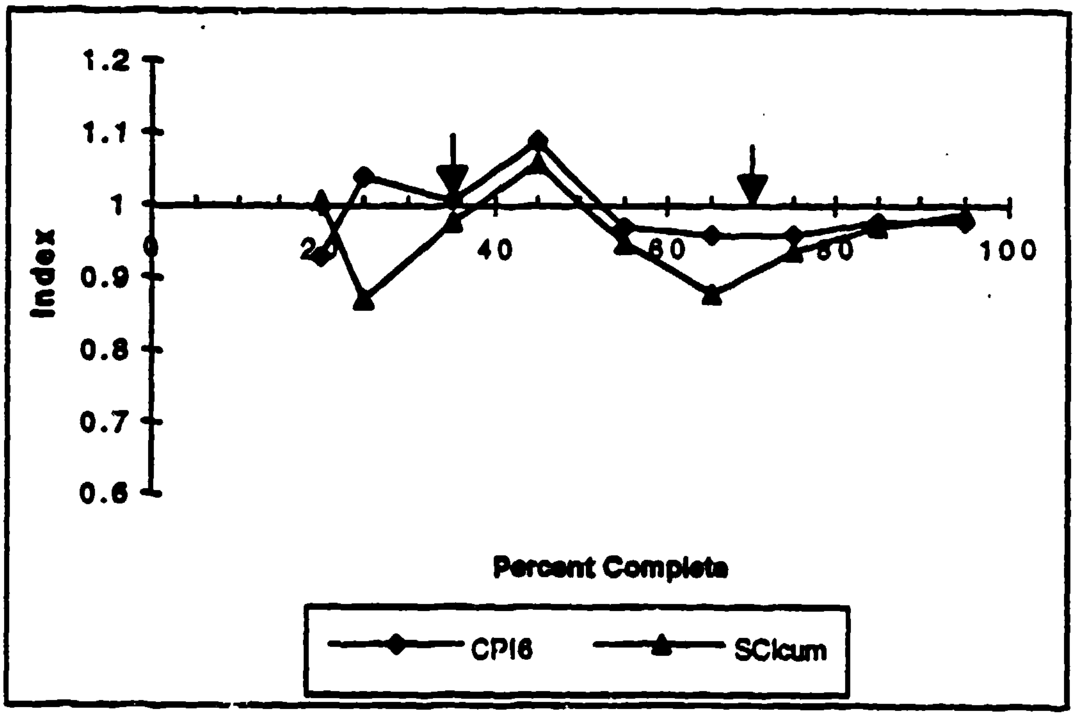

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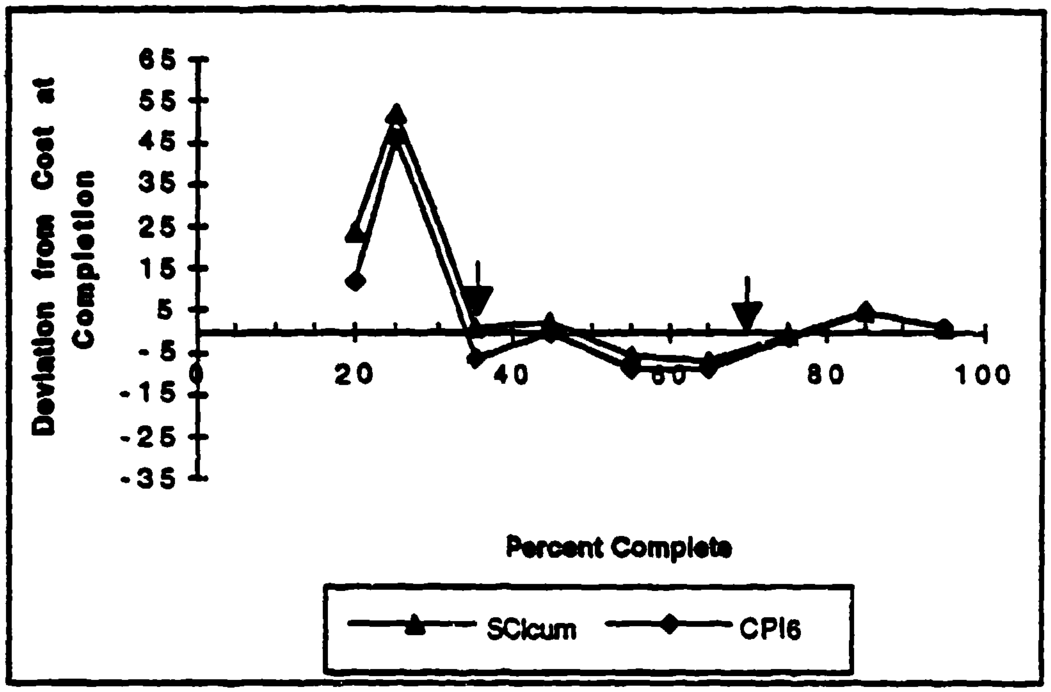

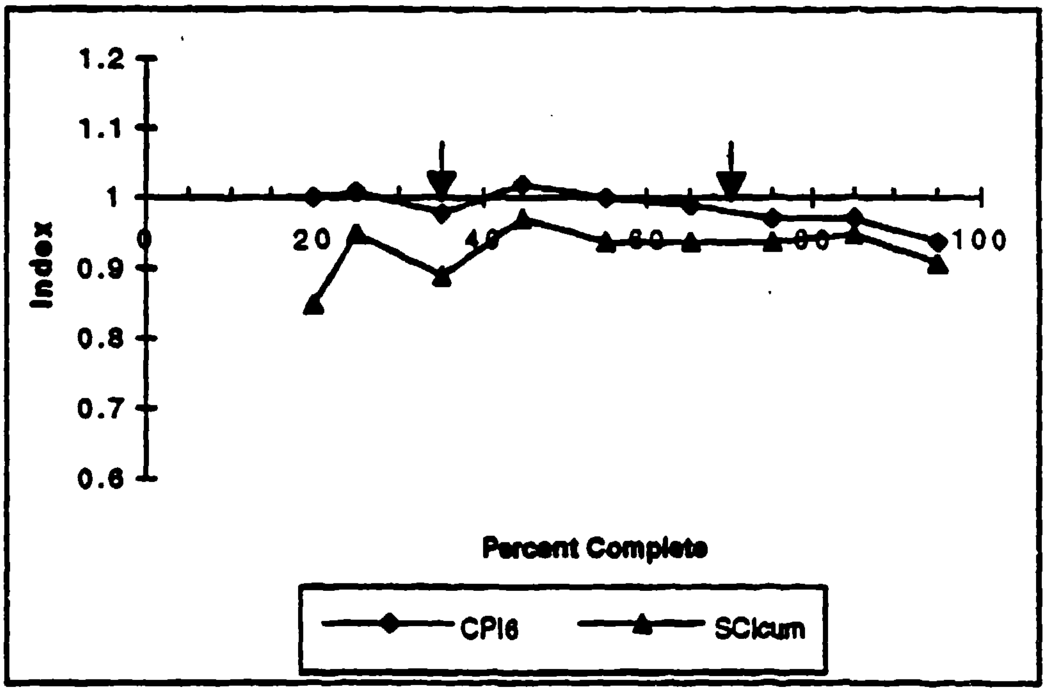

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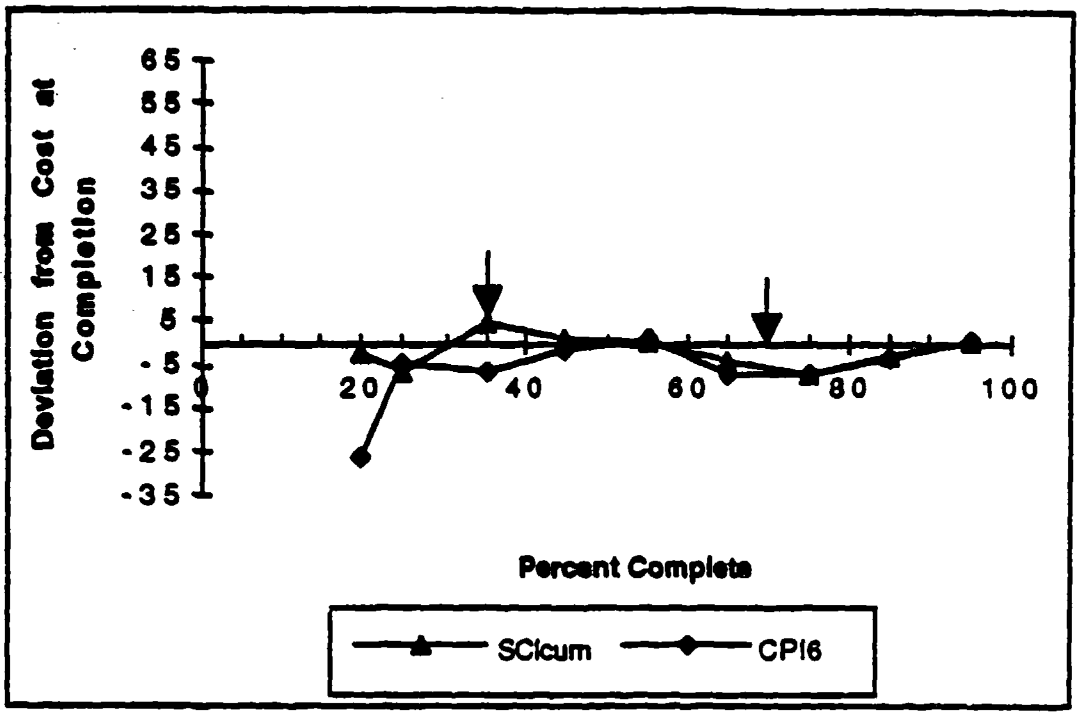

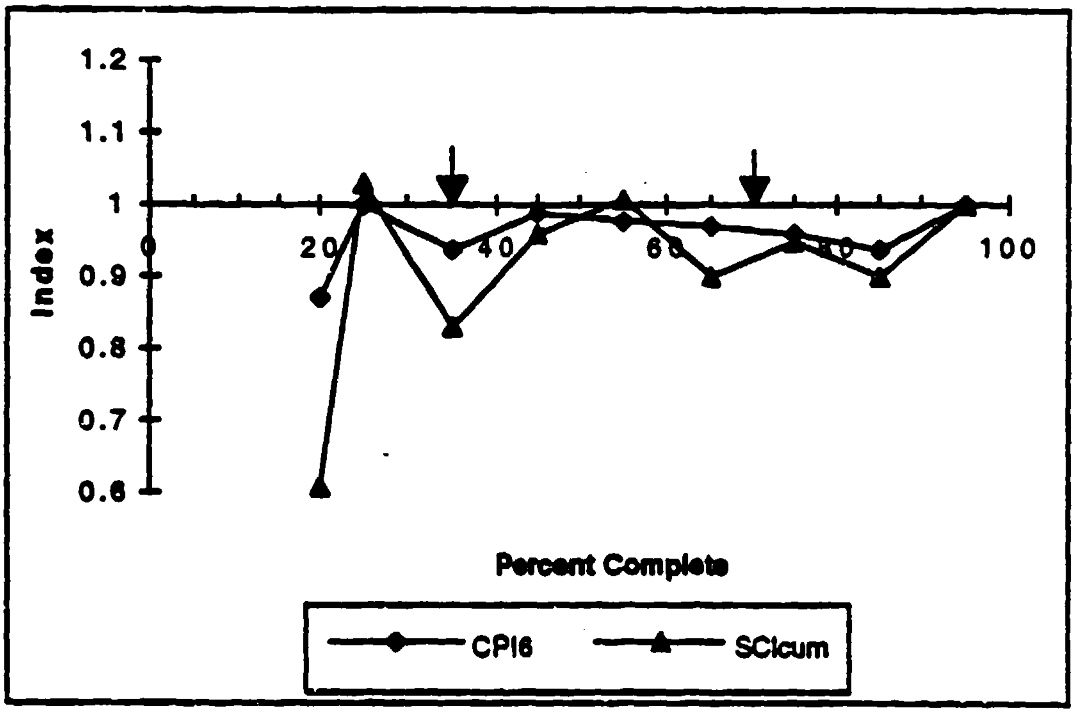

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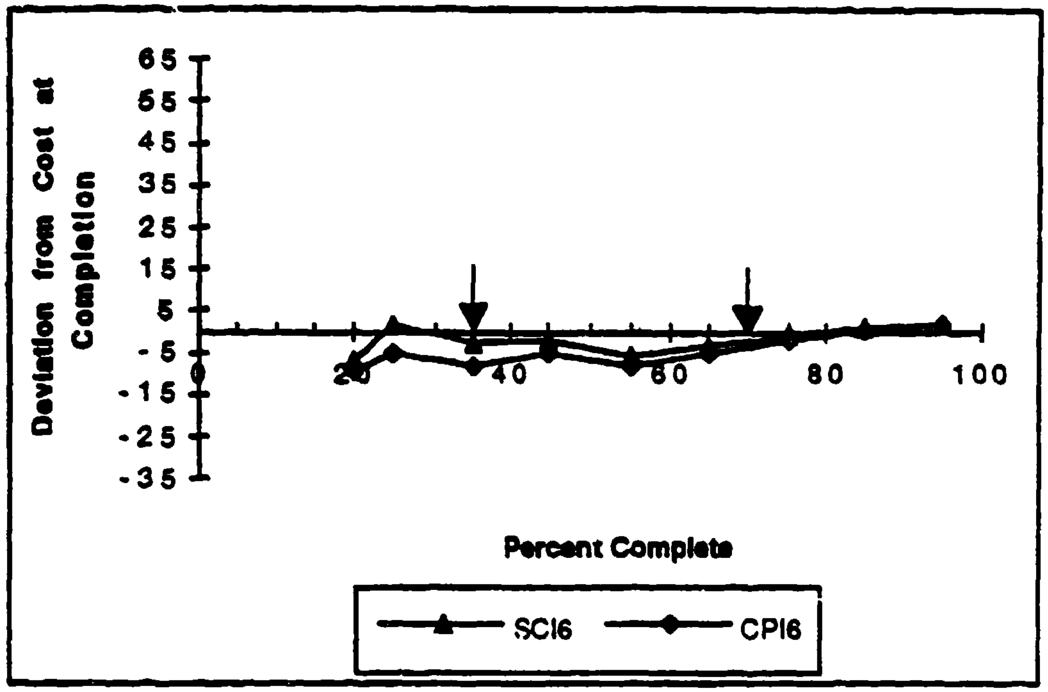

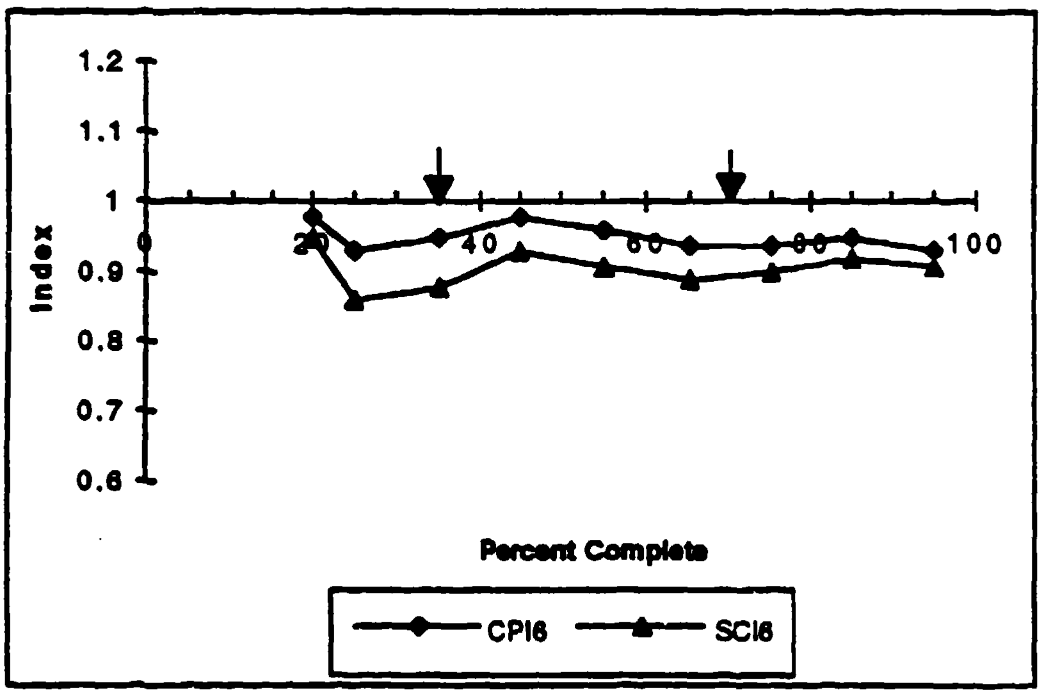

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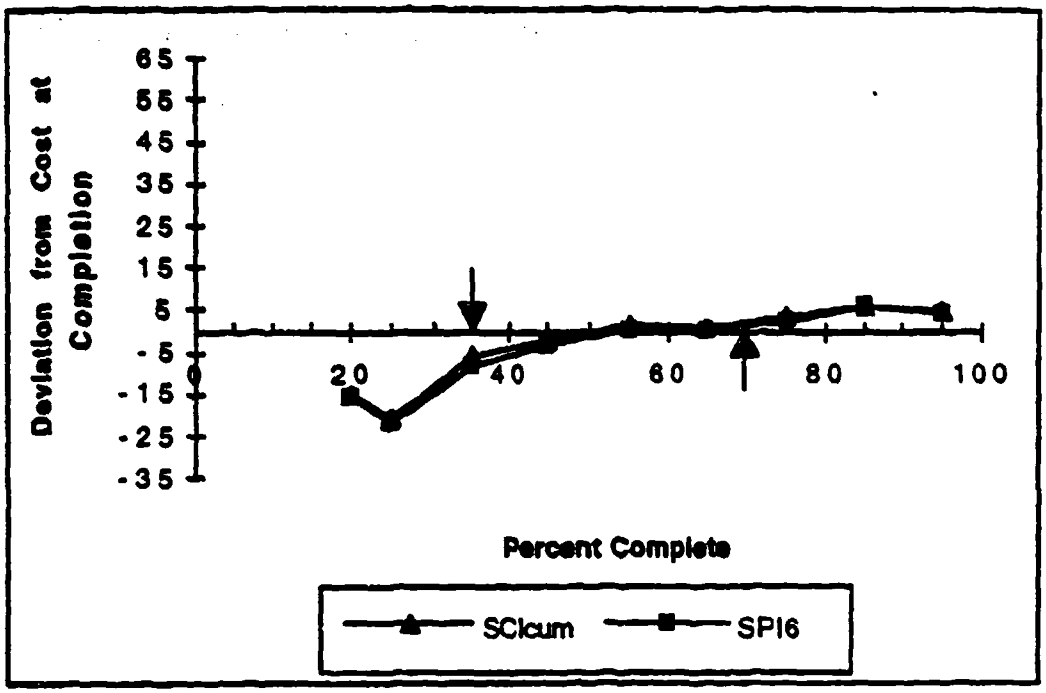

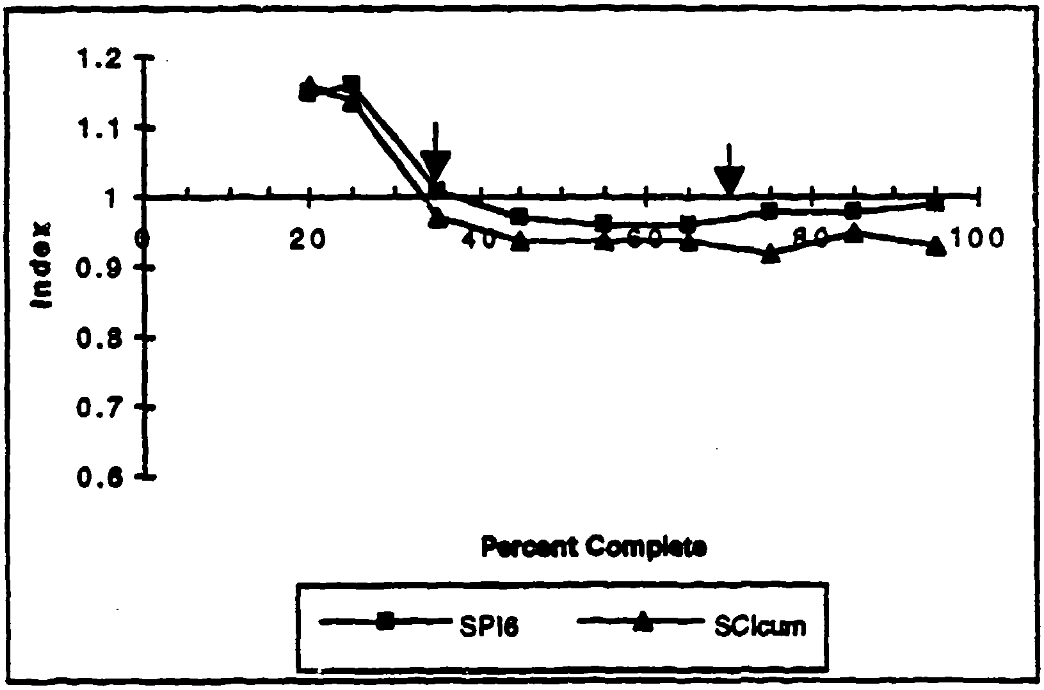

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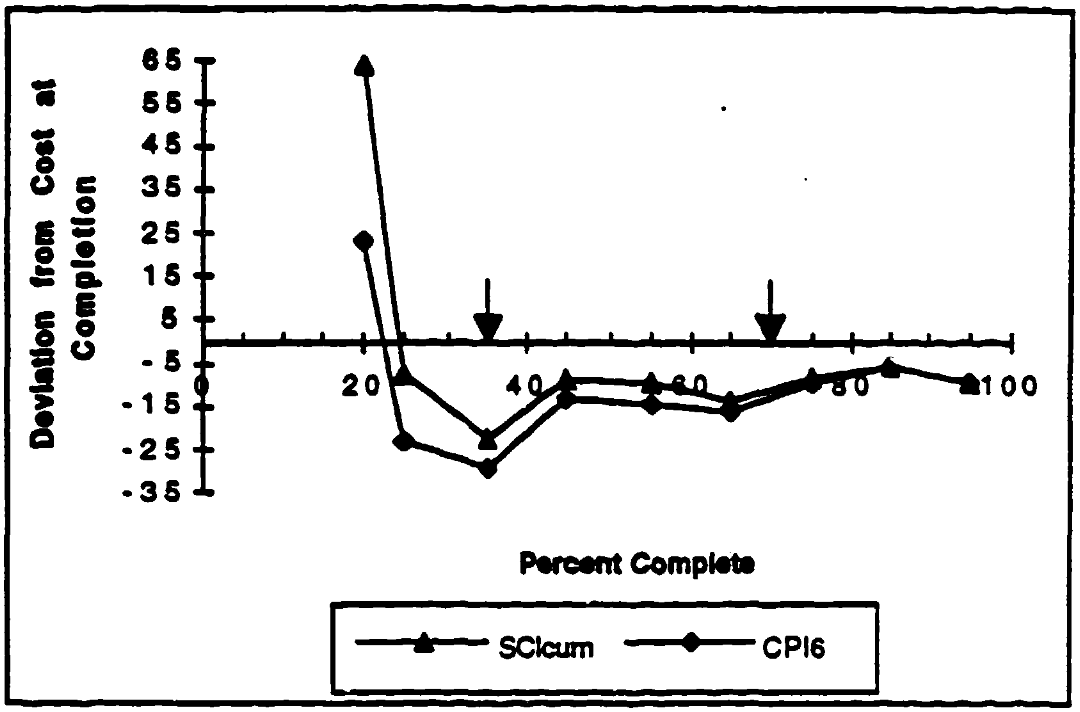

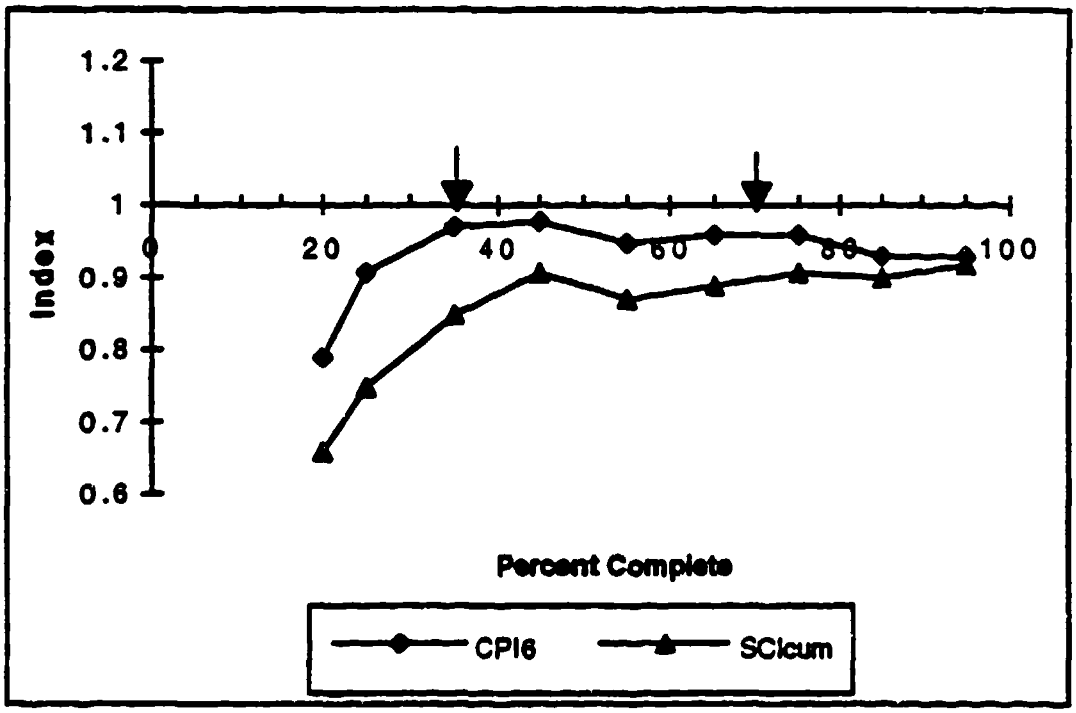

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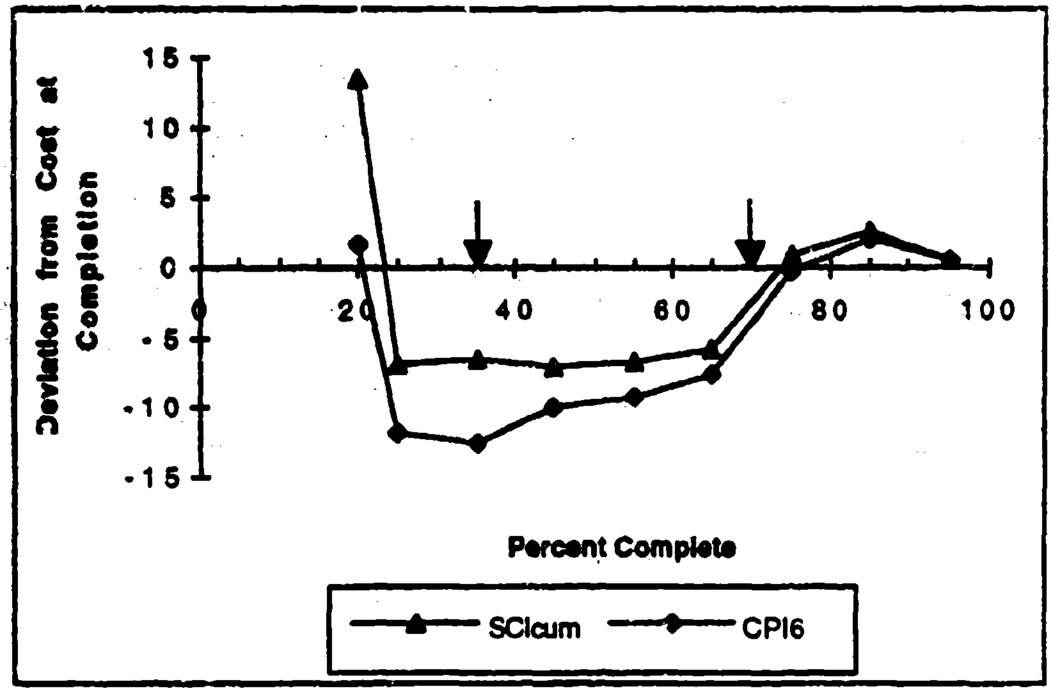
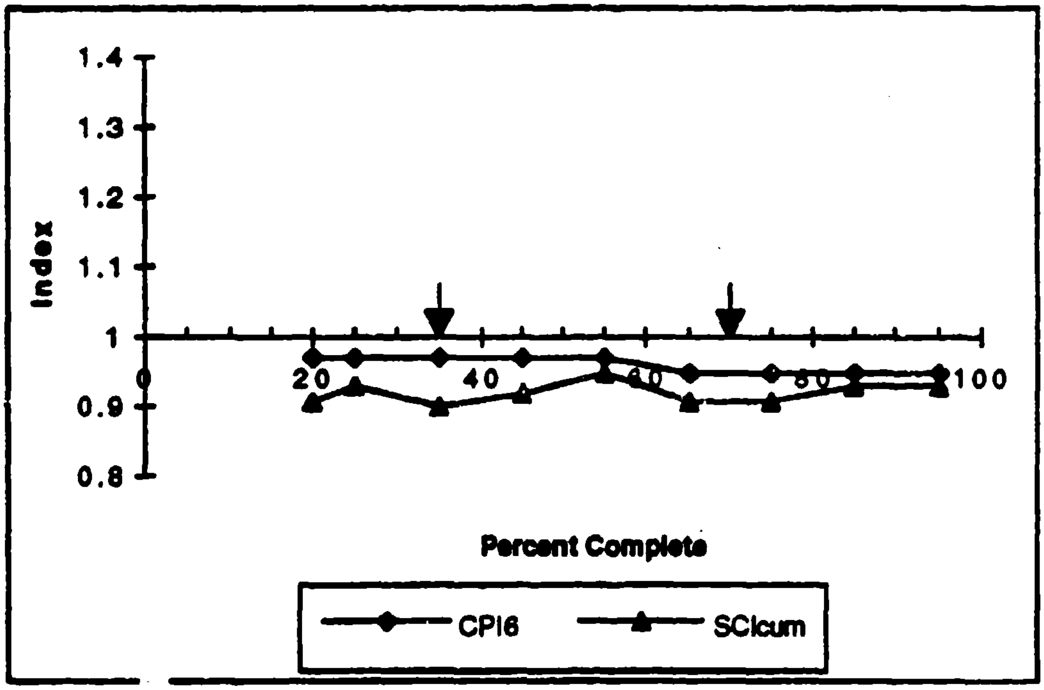
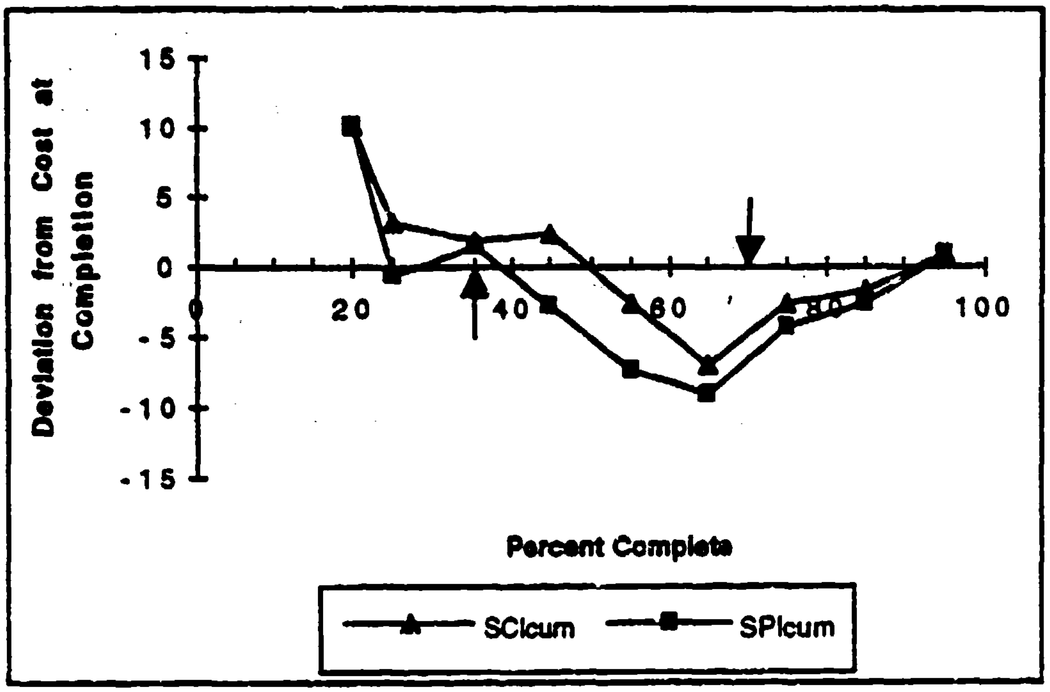
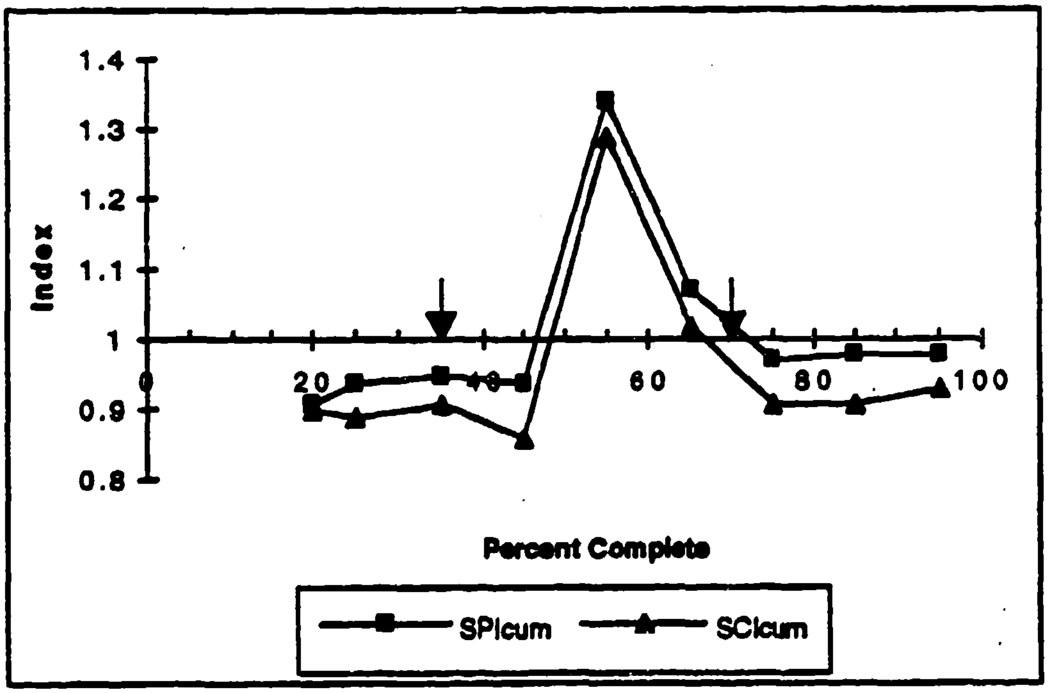




"NOT OTB" CONTRACTS INDEX & EAC GRAPHS





"OTB" CONTRACTS EAC & INDEX GRAPHS

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13. ABSTRACT *(Maximum 200 words)*

This study explores the widely held assertion that DOD contract Cost at Completion is bounded below by the Cost Performance Index-based Estimate at Completion (EAC) and above by the Schedule Cost Index-based EAC. Descriptive statistics determined the floor and ceiling for 321 DOD contracts. The results confirmed that the Cost Performance Index-based EAC is a reasonable floor and the Schedule Cost Index-based EAC is a reasonable ceiling for EAC formulas. For the contracts considered overall, on average, the Cost at Completion was not bounded by the floor and ceiling. The range of EAC formulas evaluated tended to slightly underestimate the Cost at Completion on average. Results were tested for sensitivity to Index Type (cumulative, six-month and three-month), Program Phase, Contract Type, Branch of Service, System Type, Major Contract Baseline Changes and Management Reserve. Graphs of the EAC ceilings and floors for several contract categories illustrate trends in program status throughout various states of contract completion. These graphs should assist program analysts in providing program managers with reasonable contract completion cost estimates for contracts in various categories across all stages of contract completion.

14. SUBJECT TERMS
Estimate-at-Completion, Cost/Schedule Control Systems Criteria, Forecasting, Estimating

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